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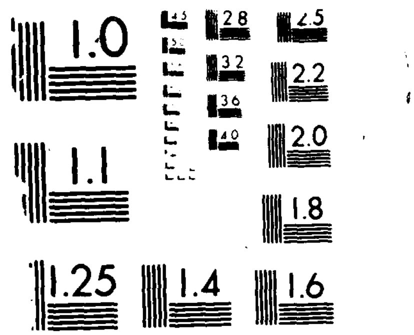
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(SUPERSEDES AFWAL TR 86-2000)

FY88

TECHNICAL OBJECTIVE DOCUMENT

AERO PROPULSION LABORATORY

MARCH 1987

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AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

JAMES L. RADLOFF, Col, USAF
Director
Aero Propulsion Laboratory

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This Technical Objective Document (TOD) has been prepared by the Aero Propulsion Laboratory to provide science and industry with specific technical objectives which the Air Force feels are critical to maintian aerospace superiority in the future. The TOD contains three functional areas (Aircraft, Missile, and Space) which provide planning objectives covering the technical disciplines of airbreathing propulsion, aerospace vehicle power, fire protection, and aircraft and missile fuels and lubrication.

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SECURITY CLASSIFICATION OF THIS PAGE

HOW TO USE THIS DOCUMENT

Unsolicited proposals to conduct programs leading to the attainment of any of the objectives presented in this document may be submitted directly to an Air Force Laboratory. However, before submitting a formal proposal, we encourage you to discuss your approach with the Laboratory point of contact. After your discussion or correspondence with the Laboratory personnel, you will be better prepared to write your proposal.

As stated in the "AFSC Guide for Unsolicited Proposals" (copies of this informative guide on unsolicited proposals are available by writing to Air Force Systems Command/PMPR, Andrews Air Force Base, Washington D.C. 20334), elaborate brochures or presentations are definitely not desired. The "ABCs" of successful proposals are accuracy, brevity, and clarity. It is extremely important that your letter be prepared to encourage its reading, to facilitate its understanding, and to impart an appreciation of the ideas you desire to convey. Specifically, your letter should include the following:

1. Name and address of your organization.

2. Type of Organization (Profit, Nonprofit).

3. Concise title and abstract of the proposed research and the statement indicating that the submission is an unsolicited proposal.

4. An outline and discussion of the purpose of the research, the method of attack upon the problem, and the nature of the expected results.

5. Name and research experience of the principal investigator.

6. A suggestion as to the proposed starting and completion dates.

7. An outline of the proposed budget, including information on equipment, facility, and personnel requirements.

8. Names of any other Federal agencies receiving the proposal (this is extremely important).

9. Brief description of your facilities, particularly those which would be used in your proposed research effort.

10. Brief outline of your previous work and experience in the field.

11. If available, you should include a description brochure and a financial statement.

INTRODUCTION

The Air Force Technical Objective Document (TOD) program is an integral part of the process by which the Air Force plans and formulates a detailed technology program to support the development and acquisition of Air Force weapons systems. Each Air Force laboratory annually prepares a Research and Technology (R&D) Plan in response to available guidance based on USAF requirements, the identification of scientific and technological opportunities, and the needs of present and projected systems. These plans include proposed efforts to achieve desired capabilities, to resolve known technical problems, and to capitalize on new technical opportunities. The proposed efforts undergo a lengthy program formulation and review process. Generally, the criteria applied during the formulation and review are responsiveness to stated objectives and known requirements, scientific content and merit, program balance, developmental and life cycle costs, and consideration of payoff versus risk.

It is fully recognized that the development and accomplishment of the Air Force technical program is a product of teamwork on the part of the Air Force laboratories and the industrial and academic research and development community. The TOD program is designed to provide to industry and the academic community, necessary information on the Air Force laboratories' planned technology programs. Each laboratory's TOD is extracted from its R&T plan.

Specific objectives are:

a. To provide planning information for independent research and development programs.

b. To improve the quality of the unsolicited proposals and R&D procurements.

c. To encourage face-to-face discussions between non-Government scientists and engineers and their Air Force counterparts.

One or more TODs have been prepared by each Air Force laboratory that has responsibility for a portion of the Air Force Technical Programs. Classified TODs are available from the Defense Technical Information Center (DTIC) and unclassified/unlimited TODs are available from the National Technical Information Service (NTIS).

As you read through the pages that follow, you may see a field of endeavor where your organization can contribute to the achievement of a specific technical goal. If such is the case, you are invited to discuss the objective further with the scientist or engineer identified with that objective. Further, you may have completely new ideas not considered in this document which, if brought to the attention of the proper organization, can make a significant contribution to our military technology. We will always maintain an open mind in evaluating any new concepts which, when successfully pursued, would improve our future operational capability.

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MANAGEMENT OVERVIEW

MANAGEMENT OVERVIEW

LABORATORY MISSION

The mission of the Aero Propulsion Laboratory is to plan, formulate, present, and execute research, exploratory development, and advanced development in the area of airbreathing propulsion, flight vehicle power, and fuels, lubricants, and fire protection. The Laboratory strives to: (1) ensure national competence, (2) avoid technological surprises, (3) stimulate technical innovation, (4) provide system support, (5) demonstrate available technology, (6) solve critical problems, (7) conduct unique research, and (8) interface with the technical community. A substantial in-house research and development effort is conducted so that the Laboratory scientists and engineers can maintain a high level of technical competence when interfacing with the scientific community. This also facilitates the evaluation of technology developed by other government agencies and the industrial complex. This Laboratory also works closely with other government agencies such as NAVY, ARMY, DARPA, NASA, etc.

INVESTMENT STRATEGY

The Aero Propulsion Laboratory's technology program is requirement oriented, stressing responsiveness to the current and future Air Force needs and a timely transition of technology to Product Divisions and the Operational Commands. These requirements are derived from a comprehensive analysis of the AFSC Vanguard Plans, Operating Commands Long Range Plans, Logistic Needs (LNs), Technology Needs (TNs), and other pertinent Air Force sources. This analysis involves both the Laboratory Planning Group and personnel from the line divisions. As in any planning cycle, the programs are responsive to changing needs, resulting in frequent reallocation of resources to the most urgent and the highest payoff areas.

In order to meet the requirements and strategy mentioned above, this Laboratory has established five (5) Strategic Objectives or Corporate goals as follows:

1. Develop and maintain a viable, productive, and relevant in-house analytical and experimental program.

2. Develop and maintain the necessary expertise and technology base needed to support current and near-term system requirements.

3. Foster and allow technological innovation and responsive technical programming.

4. Maintain and expand the technology base in our areas of responsibility.

5. Provide the necessary technology to meet far-term military requirements.

The technologies in the Aero Propulsion Laboratory fall within four (4) functional areas: (1) Manned Aircraft, (2) Unmanned Vehicles, (3) Hypervelocity Vehicles, and (4) Spacecraft. This type of groupings has two purposes. One purpose is to group requirements so that common goals can be addressed. And secondly these groupings cut across the organizational boundaries and provide a means to view all programs (whether they be turbine engines, power, fuels, or lubes) as they meet these common goals.

The requirements which were derived during Project Forecast II are listed below. Specifically, the future systems (PS's) and the future technologies (PT's) which are applicable to the Aero Propulsion Laboratory are referenced here and throughout this report.

MANNED AIRCRAFT

PS 1 Adv Intra-Theater V/STOL Transport A/C
PS 3 Multi-Role Global Range A/C
PS 4 Supersonic V/STOL Tactical A/C
PS 5 High Altitude Long Endurance A/C
PS 6 Hypersonic Intercepter A/C
PS 7 Covert/Clandestine A/C
PS 23 Adv Aerospace Plane

PT 3 High Performance Turbine Engine Technologies
PT 4 Advanced Propulsion Technology
PT 17 High Temperature Materials
PT 23 STOL/STOVL/VTOL
PT 24 Hypersonic Performance

UNMANNED VEHICLES

PT 4 Combined Cycle Engine

PS 8 Autonomous Anti-Armor Weapons
PS 9 Autonomous High Value Target Weapons
PS 12 Long Range Air-To-Air Missiles
PS 14 Hypervelocity Weapons
PS 18 Long Range Boost-Glide Vehicle
PS 47 Multi-Role Conventional Weapon

HYPERVELOCITY VEHICLES

PS 6 Hypervelocity Interceptor Aircraft
PS 23 Hypervelocity Vehicles

PT 3 High Performance Turbine Engine
PT 4 Combined Cycle Engine
PT 17 High Temperature Materials
PT 21 Cooling of Hot Structures
PT 24 Hypersonic Aero Thermodynamics

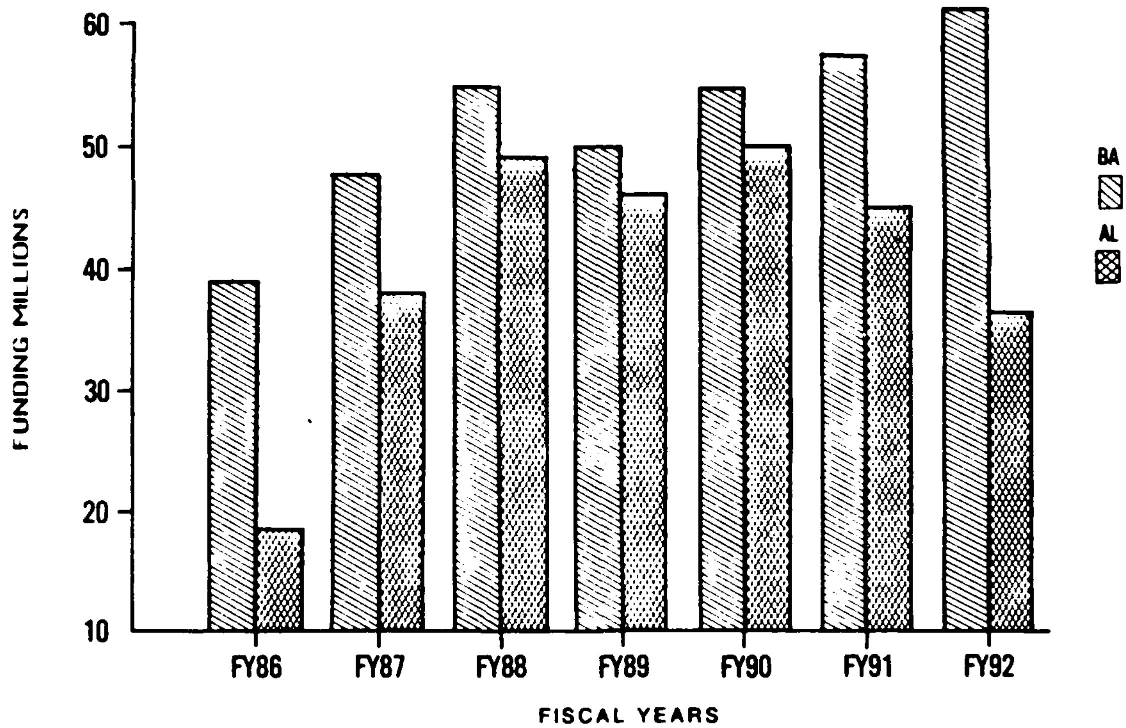
SPACECRAFT

PT 05 Space Power
PT 28 Directed Energy Technology

PS 30 Dist. Sparse Array of Spacecraft
PS 32 Space Based Surveillance System
PS 46 Space Object Identification System

The anticipated funding profile in support of Project Forecast II is shown as follows for 6.2 Exploratory Development and 6.3 Advanced Development.

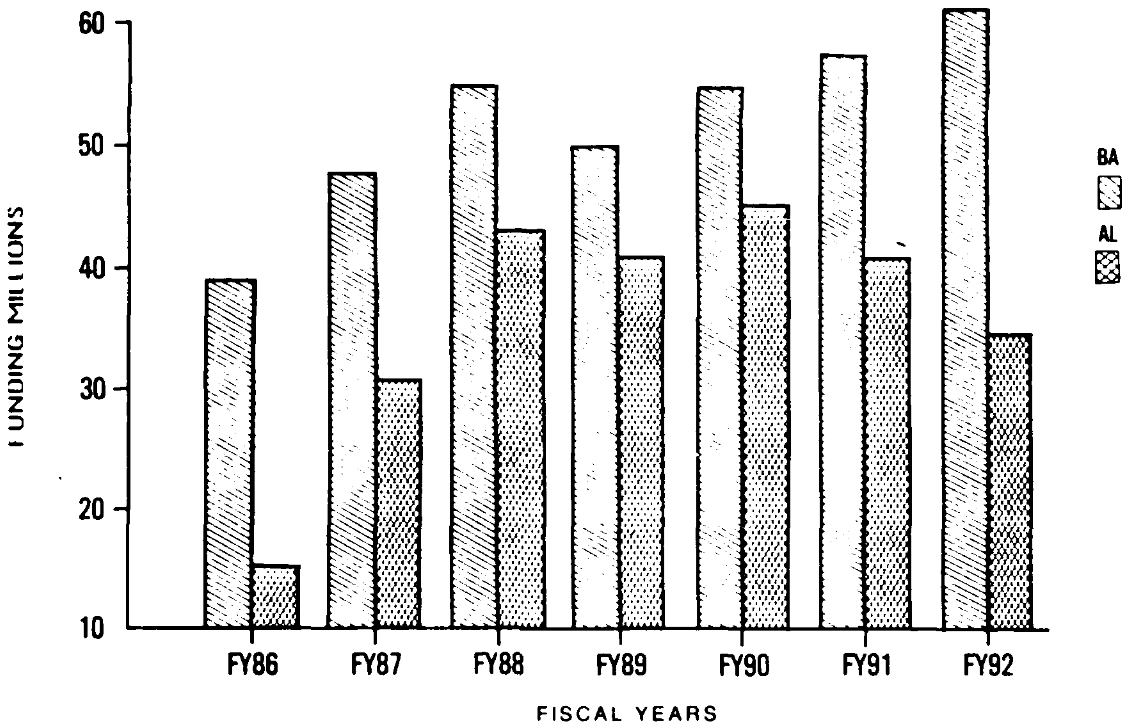
TOTAL PT & PS FUNDING
EXPLORATORY DEVELOPMENT



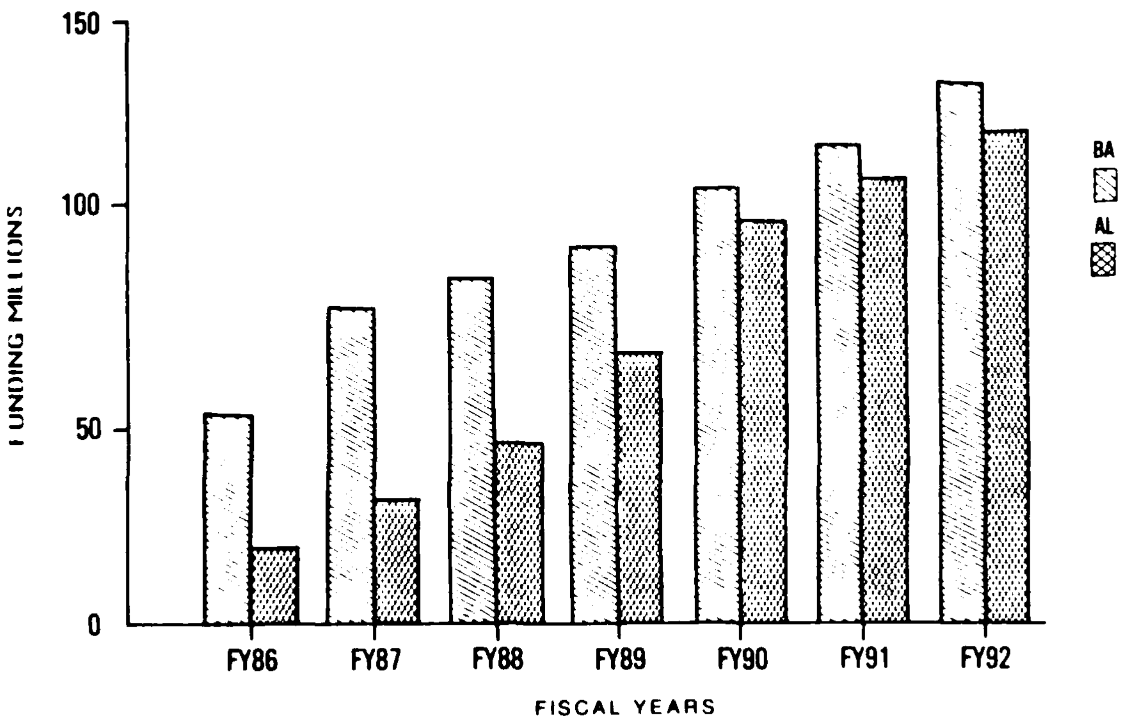
BA= Budgeted AL= Allocation

TOTAL PT FUNDING

EXPLORATORY DEVELOPMENT



ADVANCED DEVELOPMENT



RESEARCH PROGRAMS

RESEARCH PROGRAMS

INTRODUCTION

Air Force propulsion and power research programs are accomplished within the four Aero Propulsion Laboratory (APL) technical divisions: the Turbine Engine Division, the Aerospace Power Division, the Advanced Propulsion Division and the Fuels and Lubrication Division. Each APL Division performs a unique technical function for the Air Force, and research efforts attendant to this function have been established where most needed to assist these divisions in attaining the fundamental knowledge required in the performance of the development work. In consonance with the Full Spectrum Laboratory concept, the APL research program as formulated, fully supports the Air Force objectives in military propulsion and power development. The constituent research being pursued within the APL technology base includes:

Turbine Engine Division - turbomachinery fluid mechanics, aerothermodynamics, structural response in airbreathing propulsion systems.

Advanced Propulsion Division - aerodynamics, aerothermodynamics, supersonic flow.

Fuels and Lubrication Division - combustion research.

Aerospace Power Division - advanced optical measurement techniques, plasma research including gas discharges and laser plasma, electrochemistry, and spacecraft energy and thermal management research.

SPECIFIC EFFORTS

The investigative efforts are described in more detail below.

1. Advanced Optical Measurement Techniques

A. Specific Goals: (Airbreathing Propulsion)

(1) Diagnostic Techniques: Provide sensing systems for acquiring critical performance data from combustors and augmentors. Systems will eventually be applied in experimental and operational combustors. Sensing systems will utilize optical and acoustic techniques. Data to be obtained includes fuel droplet size distribution and evaporation rate, time-resolved temperature profiles, and local gas pressure, velocity, and density.

(2) Fuel Chemistry: The effects of fuel chemistry on combustor durability through heat loading and reactive species formation (chemical degradation) will be investigated. The capabilities for experiments and analysis or fuel chemistry at conditions of elevated pressure and temperature will be pursued.

B. Applications to Air Force Technology Programs: Develop diagnostic techniques for improved combustion data acquisition to support advanced modeling efforts for new aircraft engines. Devise potential maintenance tests to monitor engine performance and possibly predict failure modes. Examine electrical discharge ignition in complex gas mixtures.

2. Advanced Optical Measurement Techniques

A. SPECIFIC GOALS: (Component)

(1) Gas Laser Techniques: Measure rate constants for processes governing plasma chemical reactivity with special emphasis on the effect of internal modular energy on dissociation, electron attachment, and excited species formation in electrical discharges.

B. Application to Air Force Technology Programs: Demonstrate non-intrusive methods having high temporal and spatial resolution to probe plasma chemical processes in electrical discharge devices such as lasers, high power switches and thin film reactor plasmas.

3. Plasma Research, Gas Discharges and Laser Plasmas

A. SPECIFIC GOALS: (Directed Energy Weapons)

(1) Power Conditioning - Analyses of electron beam controlled switches, including discharge stability and plasma chemistry. Provide basic data, such as ionization, attachment, and recombination rates for insulating type gases and gas mixtures for electron beam controlled switches.

B. Application to Air Force Technology Programs: Demonstrate feasibility of using a plasma as a high power, high repetition, on/off switch for large directed energy devices, particularly those using inductive energy storage sub-systems.

4. Plasma Research Gas Discharge and Laser Plasmas

A. SPECIFIC GOALS: (Components)

(1) Gas Laser Techniques - Develop the technology of long lifetime, compact, closed-cycle flowing gas lasers. Provide wavelength versatility combined with pulse modulation at intermediate power ranges which would be suitable for specialized AF requirements as well as research. Provide efficient power conditioning interfaces between high frequency pulsed discharge lasers and high voltage power supplies.

(2) Advanced Processing Methods for Submicron Structures - Identify and model the plasma chemistry occurring in plasma reactors during thin film formation and plasma etching.

B. Application to Air Force Technology Programs: Optimum performance of advanced laser devices for a variety of Air Force missions require in-depth understanding of the laser plasma characteristics. Advanced electronic devices, such as VSHIC chips, will require more efficient, more reliable production methods having improved spatial resolution. An increased understanding of the plasma used for thin film deposition and etching will enhance these fabrication characteristics. Thin film deposition techniques are important for high quality optical components for laser devices and surveillance systems, lighweight thermal management sytems for satellites and catalytic surfaces for chemical processing systems.

5. Structural Response in Airbreathing Propulsion Systems

A. SPECIFIC GOALS: (Air Breathing Propulsion)

(1) Structural Dynamics - Observe, characterize and model turbomachinery bladed disk aeromechanical phenomena. Analyze and model turbine engine dynamic phenomena. Investigate novel diagnostic techniques for characterizing the turbomachinery structural and thermal environment.

(2) Aeroelasticity - Observe, characterize and effectively model three-dimensional transient and steady-state pressure distributions on bladed disk assemblies (compressor/turbine environments) resulting from subsonic, transonic, and supersonic flow regimes. Generate aero-structural mathematical models of bladed disks operating in realistic turbine engine environments.

B. Application to Air Force Technology Programs: Ascertain significant aero-mechanical phenomena to be incorporated into improved analytical models of bladed disks. Provide the analytical tools to predict the aeromechanical response and durability of advanced bladed disk systems. Develop diagnostic techniques for definition of the hostile turbine engine environment.

6. Electrochemistry

A. SPECIFIC GOALS: Power Generation and Distribution

(1) Mid-Term Battery Requirements - Define the nature of active material shedding which limits nickel electrode life. Investigate sodium-sulfur cell separators to extend cycle life. Elucidate the reactions occurring the lithium ploymer cells. Perform micromorphology studies on lithium cells to define its applicability to cell condition determinations. Continue high energy density rechargeable cell investigations.

(2) Long-Term Battery Requirements - Evaluate low temperature molten salt electrolytes and ambient temperature non-aqueous electrolytes for potential application in high energy density rechargeable batteries. Study the electrochemistry associated with very high current discharge (for short time periods) delivered by either primary or rechargeable batteries. In the case of secondary cells, maximum discharge rates and power density will also be investigated. Explore the electrochemical aspects of lithium rechargeability in combination with various potential cathodes. Polymer electrode kinetics and energy densities will be studied for high energy density rechargeables.

B. Application to Air Force Technology Programs: Provide the technology required for the development of advanced rechargeable spacecraft and aircraft batteries. Improve the shelf life, safety and performance of high energy density primary cells for eventual application in life support equipment, missiles, ground support systems, munitions and remotely piloted vehicles. Demonstrate the electrochemical concepts required to permit the design of batteries which can provide very high pulses of power for such potential systems as directed energy weapons and space based radars.

7. Turbomachinery Fluid Mechanics

A. SPECIFIC GOALS: (Air Breathing Propulsion)

(1) 3-D and viscous Phenomena - Identify and quantify the principal viscous effects present in three-dimensional compressor flow fields and develop the means to account for them in design and analysis codes.

(2) Nonsteady Blade Row Interactions - Develop an approach to compressor design taking into account the nonsteady effects associated with multistaging.

B. Application to Air Force Technology Programs: Verify design and analysis concepts potentially providing major increases in compression system efficiency for aircraft turbine engines. Develop and verify improved mathematical models for multistage compressor flow fields contributing both to improved performance and reduced time and cost for compression system development.

8. Aerothermodynamics

A. Specific Goals: (Fluid Dynamics and Aerothermodynamics)

(1) Turbulence Model Development - This task is to investigate turbulence models which can improve the accuracy of the computation to heat transfer from flows with high free stream turbulence levels.

(2) Engine Turbulence Measurements - This task is to define the fluctuation properties of the free stream at the entrance to the turbine engine.

(3) Cool Combustor Measurements - This task is to characterize the turbulence properties of model and actual full scale combustors in which the high and low temperature properties are characterized by fluids of the appropriate densities.

(4) Shock Tube Measurements - This task is to exploit the shock tube to obtain experimental heat transfer data. Two shock tubes are used to further develop heat transfer relations through student and faculty research. Seeding techniques, transient data acquisition, and window treatments for laser velocimeter applications are also developed in the shock tubes. A shock tube is the driver for a full scale rotating turbine exploratory development heat transfer test. This task is also developing the optical turbulence measuring techniques to be used with the exploratory heat transfer measurements.

(5) Flat Plate Measurements - This task is primarily coordination of the computations from previous tasks with the flat plate measurements.

(6) Turbulent Prandtl Number Experiment - This task is for the design and partial fabrication of a large scale experiment which will allow access to the entire boundary layer. This experiment will require a turbulence generator capable of generation of turbulence with independently variable scale and intensity.

(7) Non Steady Flow and Heat Transfer - This task is to investigate a periodic disturbances interaction with a laminar boundary layer using Hankey and Shangs' time dependent calculations.

(8) Instrumentation - This task is for the procurement of traverse hardware, particle size measurement hardware, seeder hardware, transient data storage capability, air calibiatory, and consumable probes. This instrumentation is considered over ceiling but highly desirable.

B. Application to Air Force Technology Programs

This effort is to provide improved accuracy in the heat transfer relationships in flows with high free stream turbulence levels. These relationships significantly affect the life time and performance of turbines, combustors, and the associated hot section components. The ability to accurately predict heat transfer allows the reduction in cooling air, higher turbine operating gas temperatures, improved specific fuel consumption, and increased hot section lifetime.

9. Ramjet Research

A. SPECIFIC GOALS: (Airbreathing Propulsion)

(1) Turbulent Recirculating Flowfield Investigation - Establish a benchmark set of turbulence data in non-reacting flows to evaluate and improve models of turbulent reacting flows with recirculation zones.

(2) Turbulent, Recirculating Flow Models - Develop new solution algorithms for solving 2 and 3 dimensional turbulent recirculating flows. Evaluate models for turbulence, kinetics and spray combustion. Develop time-dependent models for turbulent recirculating flows.

(3) Break-up of Liquid Jets in High Speed Cross Flows - Establish the effects of physical properties, state variables and flowfield velocity and turbulence on the breakup of liquid jets in high speed cross flows.

(4) Flame Stabilization and Propagation in Supersonic Flows - Investigate piloting energy requirements, flame stabilizer exchange characteristics and low temperature auto ignition characteristics for hydrogen and hydrocarbon fuels in supersonic flows.

2. Application to Air Force Technology Programs: Provide the analytical tools to develop/improve ramjets and ducted rockets. Reduce the amount of expensive testing required to develop ramjet engines. Expand the operating envelope for airbreathing missile systems.

10. Spacecraft Energy and Thermal Management Research

A. SPECIFIC GOALS: (Power Generation and Distribution)

(1) Advanced Radiator Concepts Research - Investigation of combined heat and mass transfer phenomena application to steady and pulsed power spacecraft radiators and thermal protection of spacecraft. The goals of this research are to

provide an order of magnitude decrease in the specific mass of the radiator (presently 5kg/m^2) for steady state heat refection, with similar reductions in pulsed power expendable coolant penalties.

(2) Two-Phase Heat Transfer Research - Investigation of steady and unsteady heat transfer mechanisms in two-phase fluid flow and thermal storage media applicable to high transport capacity (10 KW-M), high heat flux (100KW/m^2), and/or pulsed power (100/1 peak/average) heat rejection applications. these performance goals represent order of magnitude increases over present technology capabilities.

(3) Evaporative Cooling with High Heat Fluxes - Investigation of removing high heat fluxes (500 - 2000 W/cm^2) from a cold plate surface while maintaining the surface temperature at or below a nominal 100 C required for electronic payload cooling. At these heat fluxes, fluid transport will be impeded by vapor entrainment effects which, coupled with an increased superheat penalty, severely limits the possibility of a nominal 100 C payload. The understanding of the physical phenomena to reduce these penalties is necessary in order to establish a design theory base for high heat flux cold plates.

B. Application to Air Force Technology Programs - The research pursued under this task is intended to lead to enabling technology breakthroughs applicable to spacecraft electrical power and thermal management subsystems. A portion of the work will also lead to a more complete understanding of the performance of more conventional, evolutionary technologies where radiation and phase-change heat transfer phenomena are not fully characterized, understood, and/or utilized.

TECHNOLOGY PROGRAM

MANNED AIRCRAFT

TURBINE ENGINE TECHNOLOGY

The purpose of the project is to conduct exploratory development on advanced turbine engine component technologies to provide superior turbopropulsion and combined airbreathing propulsion systems for future Air Force mission applications. This project develops technology to increase propulsion system operational reliability, cycle flexibility, and performance while reducing fuel consumption, weight, and cost. Both analytical and experimental efforts are conducted in fans and compressors, high temperature combustors, turbines, and seals, controls, diagnostics, exhaust systems, and structural design techniques. This project considers the total propulsion system (inlet, engine, nozzle), and its integration into a weapon system. A large portion of this Project (50-70% of available resources) will be in support of the High Performance Turbine Engine Technologies (HPTET) program, a joint Aero Propulsion/Materials Laboratory technology development initiative. The goal of HPTET is to integrate efforts to provide, by the year 2000, the technologies necessary to double turbine engine capability (e.g., 20:1 thrust-to-weight ratio fighter engine). These technologies will transition to the Aircraft Propulsion Subsystem Integration (PE 63202F) and Advanced Turbine Engine Gas Generator (PE 63216F) for validation and advanced development.

FY 1986 Program - The technology development program planned under Project 3066 for FY 1986 continued to concentrate on component development efforts advanced heat transfer concepts, and structual/material innovations. More than 50% of Project resources for FY 1986 were in support of the Laboratory's HPTET program. Accomplishments of particular significance during FY 1986 included the successful fabrication of a high specific modulus titanium metal matrix composite shaft, a design which will permit fewer bearings and a simplified lubrication system. The results of this work contribute directly to the goals of HPTET. Likewise, recent advances in computational fluid dynamics have made it possible to analyze the efforts of unsteady interactions (wakes, shocks, pressure waves) on the performance and cooling efficiency of turbine airfoils--vanes and blades. In addition, during FY 1986 emphasis was placed on the in-house development and implementation of a new turbine heat transfer and cooling research program to provide bench mark, high quality experimental data in the areas of turbine vane and blade heat transfer, cooling air distribution and turbine airfoil aerodynamics. Preliminary test facility design and necessary equipment layout were completed and a detail design contract was established. In support of the Expendable Turbine Engine Concepts (ETEC) advanced development program technology development for high temperature (2400 F+) hot section components (carbon-carbon and ceramic combustors, slurry combustion, and cooled turbines) and advanced compressors for potential future supersonic missile propulsion were continued. HPTET efforts initiated in FY 1986 include an enhanced flow compressor development for high Mach (up to Mach 6) turbine engines and an advanced high-work turbine development for intermediate (15:1 class thrust-to-weight HPTET levels).

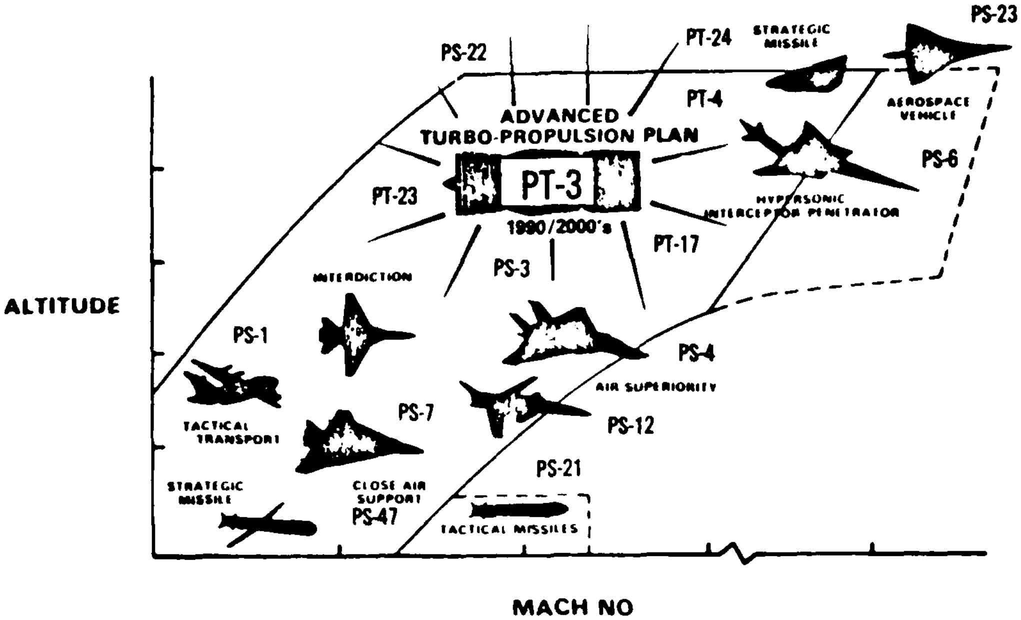
FY 1987 Planned Program - Efforts to be completed will be two vane/blade interaction programs modeling the aerodynamic and heat transfer coupling between a cooled turbine vane and blade in a high-temperature gas path environment. Complementing this work will be the Turbine Cooling System Design Program providing an advanced turbine heat transfer design code for

improved film cooling. Programs on composite disk life prediction, hot section component development for limited-life missile propulsion applications, and integrated/performance-optimized control logic will also be completed in FY 1987. A number of ongoing and planned programs dealing with the development and application of advanced, innovative, nonintrusive instrumentation will be conducted to support increasing requirements for accurate, reliable engine and component stress/strain, temperature and pressure data. Ongoing and planned compressor, combustor, and turbine component design system developments incorporating complex 3-D aerodynamics, composite structure stress predictions and advanced heat transfer codes will depend heavily on the successful application of these new measurement systems for effective computer prediction model code validation. In addition, the initial study phase of the high Mach enhanced flow compressor development for high Mach turbine engines will be completed from which ultimate program direction, payoff and key technology requirements will be defined for both man-rated and limited-life systems--subsequent Phases will be based on the results of this initial study. Major HPTET component development efforts will be initiated in FY87 using the Program Research and Development Announce (PRDA) as the procurement approach. The single PRDA will solicit proposals covering all engine components, including innovative structures, lightweight controls and accessories, secondary flows, and (in conjunction with Project 3048) bearings, Lubricants, and Lubrication systems. Ten to twenty advanced component developement efforts will result from this PRDA, primarily targeted for intermediate (1992-95) technology demonstration. All of these technology developments will transition to the Aircraft Propulsion Subsystem Integration (PE 63202F) and Advanced Turbine Engine Gas Generator (PE 63216F) for advanced development.

FY 1988 Planned Program - During FY 1988, nearly 50 percent of the Project 3066 budget allocation will be dedicated to demonstrating and maturing competitive HPTET component technologies preparatory to transition to the Advanced Turbine Engine Gas Generator program (PE 63216F). Specifically, major emphasis will be placed on ongoing compressor, combustor, turbine and innovative structural design efforts leading to interim component and engine demonstrations consistent with early 1990s HPTET goals. The following technical issues will receive priority attention in support of HPTET: (1) damage tolerant, very high temperature composites and fiber reinforced engine structures; (2) near-stoichiometric hot section designs; (3) damage tolerant Titanium Aluminide metal matrix composites; (4) compact hi-flow compression systems; (5) hi-temperature bearings/lube systems; (6) multifunction, lightweight controls/accessories; and (7) hi-temperature metal alloys and refractory materials. The scope of effort dealing with each of these issues will be a function of available HPTET program resources. Within the compressor area, a significant technology demonstration will occur in FY 1988 using the Laboratory's Compressor Research Facility--multistage performance and matching of swept-rotor aerodynamics. Most of the technical efforts resulting from the FY87 HPTET PRDA will begin in FY88. No major HPTET procurements are planned for FY88. (The large HPTET PRDAs will be initiated every two or three years.) Depending on funding availability, a number of generic programs are planned for FY 1988. These would include Integrated Control Law Evaluation--Model Validation, combustion turbulence and swirler aero research.

HIGH PERFORMANCE TURBINE ENGINE TECHNOLOGY INITIATIVE

• REVOLUTIONARY ENGINE TECHNOLOGY FOR A WIDE RANGE OF WEAPON SYSTEMS

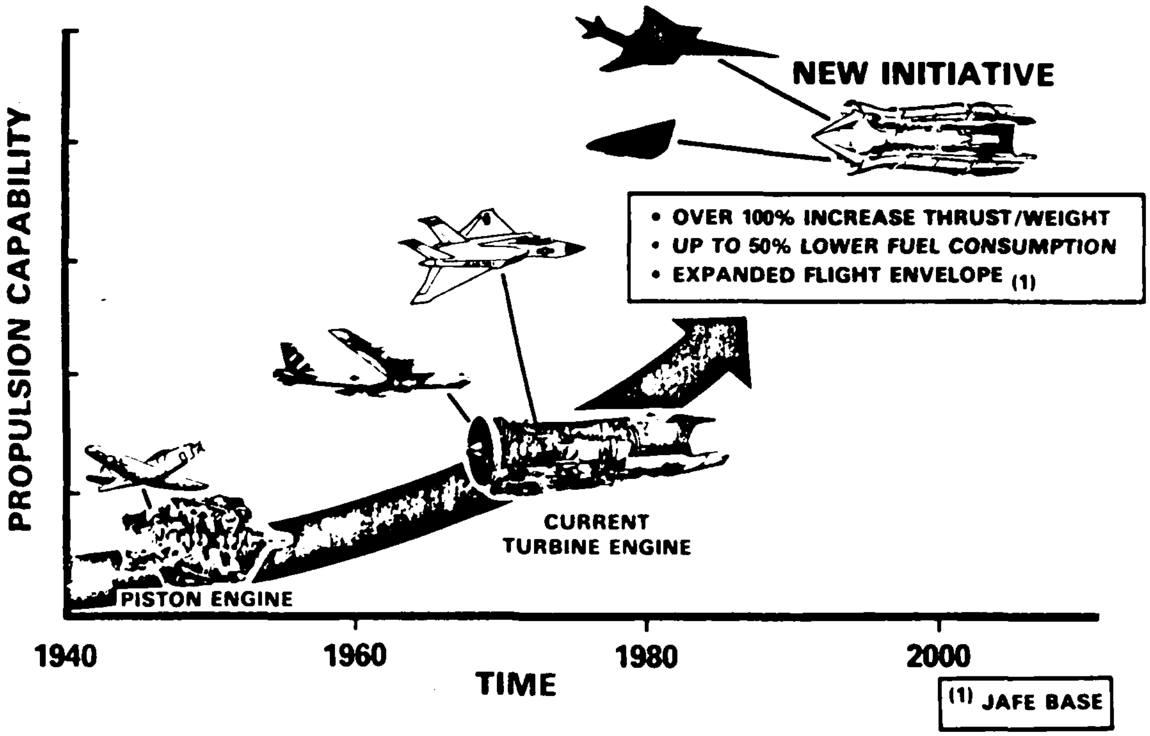


FORECAST II SYSTEMS AND TECHNOLOGIES SUPPORTED

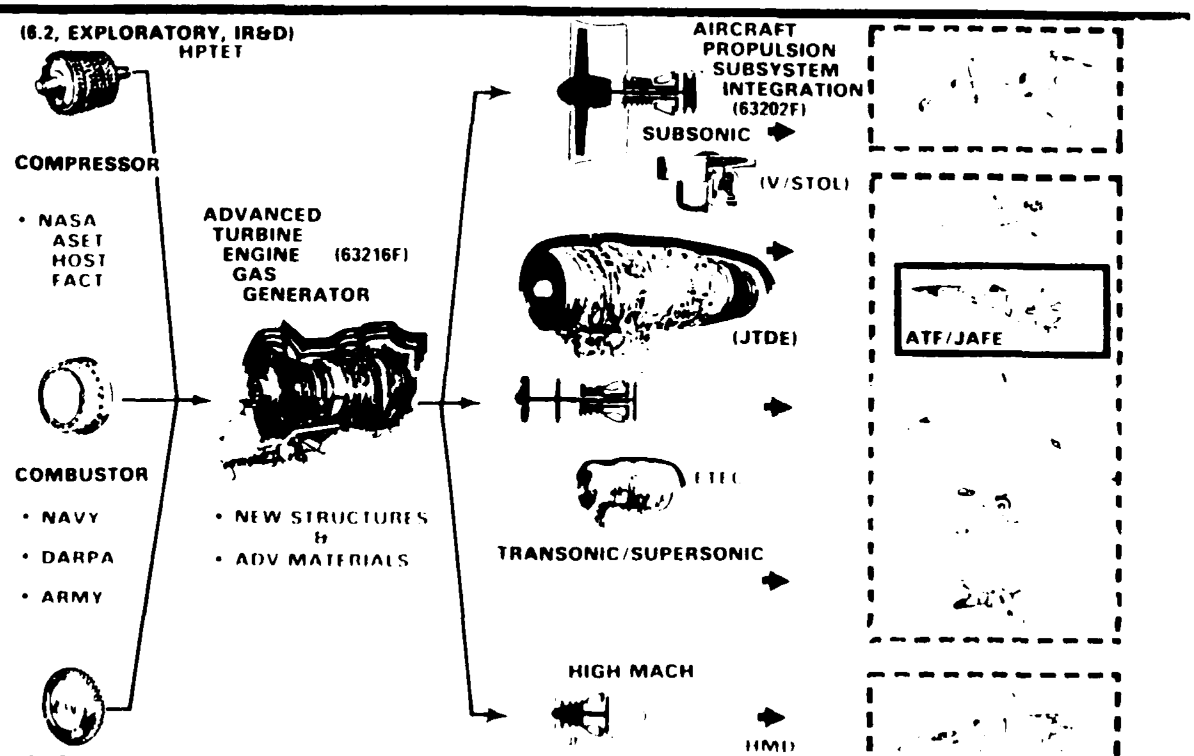
PS 1	ADV INTRA-THEATER V/STOL TRANSPORT A/C
PS 3	MULTI-ROLE GLOBAL RANGE A/C
PS 4	SUPERSONIC V/STOL TACTICAL A/C
PS 5	HIGH ALTITUDE LONG ENDURANCE A/C
PS 6	HYPERSONIC INTERCEPTER A/C
PS 7	COVERT/CLANDESTINE A/C
PS 12	LONG RANGE AIR-AIR WEAPONS
PS 21	TACTICAL LOW COST DRONES
PS 22	MULTI-MISSION REMOTELY PILOTED VEHICLE
PS 23	ADV AEROSPACE PLANE
PS 47	MULTI-ROLE CONVENTIONAL WEAPONS
PT 3	HIGH PERFORMANCE TURBINE ENGINE TECHNOLOGIES
PT 4	ADVANCED PROPULSION TECHNOLOGY
PT 17	HIGH TEMPERATURE MATERIALS
PT 23	STOL/STOVL/VTOL
PT 24	HYPERSONIC PERFORMANCE

U.S. MILITARY AIRCRAFT PROPULSION

• NEW INITIATIVE WILL DOUBLE PROPULSION CAPABILITY BY TURN-OF-THE-CENTURY



ADVANCED TECHNOLOGY DEVELOPMENT



HIGH PERFORMANCE TURBINE ENGINE — KEY TECHNOLOGIES —

- COMPETITIVE DEVELOPMENT OPTIONS FOR BOTH AIRCRAFT AND MISSILE PROPULSION

ADVANCED AERO + NEW MATERIALS + INNOVATIVE DESIGN

- 3-D VISCOUS CFD DESIGN TOOLS
- SWEPT AIRFOILS
- STOICHIOMETRIC COMBUSTORS
- ADVANCED COOLING CONCEPTS
- HIGH COMPRESSOR STAGE LOADING
- SHORT EXHAUST NOZZLES
- VARIABLE CYCLE FEATURES
- VANELESS LP TURBINES
- UNIQUE COMBUSTOR DIFFUSERS

- LIGHTWEIGHT COMPOSITES
  - CARBON CARBON
  - CERAMIC
  - METAL MATRIX
- Ti & Ni ALUMINIDES
- VERY HIGH TEMP Al & Ti
- CERAMIC BEARINGS
- NON STRUCTURAL MAT'LS
  - HI TEMP & DRY LUBES
- REFRACTORY METALS

- FIBER-REINFORCED STRUCTURES
  - RING ROTORS
  - BLADES
  - STATIC STRUCTURES
- MULTI-USE STRUCTURES
- SIMPLIFIED ROTOR SUPPORTS
  - INTEGRAL PEDESTAL
  - SUPPORT SPOKES
- INTEGRAL BLADING
- LAMINATED STRUCTURES
- ENDOTHERMIC FUELS

COMPETITIVE INDUSTRY EFFORTS: ALLISON, GENERAL ELECTRIC, GARRETT, TELEDYNE PRATT & WHITNEY, WILLIAMS

PROJECT 3066 - TURBINE ENGINE TECHNOLOGY

OBJECTIVE

TO PROVIDE ADVANCED TURBINE ENGINE COMPONENT TECHNOLOGIES WHICH WILL ASSURE SUPERIOR TURBOPROPULSION SYSTEMS FOR FUTURE AF MISSIONS

FUNDING ($M)

FY	87	88	89	90	91
	18.2	24.7	20.5	21.3	21.8
% HPTET DEDICATED	64%	68%	66%	75%	80%

MILESTONES

ADV CONCEPT COMP RIG DEMO	12/86
AWARD OF HPTET MULTI-OPTION CONTRACTS	9/87
COMP 3D SHOCK-LOSS MODEL VALID	9/87
ADV TURBINE COOLING DES SYSTEM AVAILABLE	2/88
NON-METALLIC COMBUSTOR DEMO	4/89

ADVANCED TURBINE ENGINE GAS GENERATOR (ATEGG) - The Advanced Turbine Engine Gas Generator (ATEGG) Program is responsible for demonstrating integrated advanced gas generator technology for turbine engines. The specific objective of ATEGG is to provide for the functional, engine-level demonstration of new core engine design technologies (design tools, rules and systems) found on advanced high pressure compressors and turbines, and combustors. Advanced core engine design capability is necessary to ensure continued advancements in turbine engine propulsion capability. Under ATEGG, the latest advanced component design technologies and concepts are integrated into experimental gas generators and critically tested and evaluated under actual engine operating conditions. Emphasis is placed on developing the analytical design tools and systems for assessing and predicting and performance of the advanced technologies. Completion of this testing establishes confidence that the designs can be refined in future advanced engine developments, or utilized for improvements in existing engines.

Current programs include large and small engine core technology developments. The following is a list of some specific features of technology by component.

Component	Technology
Advanced Compressors	3D Viscous Aerodynamics Lightweight Blisk Structures Dual Alloy Centrifugal Impellers Blade Tip Durability Treatments Advanced Seals Titanium Aluminide Airfoils Variable Cycle Concepts Reduced Parts Count
Advanced Combustors	Reduced Pressure Loss Aerodynamics Unrestricted Flight Envelope Sector Burning/Staged Combustion Dual Wall Designs Lightweight Liners/Short Length Improved Pattern Factor Improved Life Prediction System
Advanced Turbines	Enhanced Film Cooling/Shaped Holes Multi-Piece Fabrication Reduced Tip Clearance/Ceramic Blade Tip Shrouds Advanced Single Crystal Airfoils Advanced Disk Alloys Boltless Blade Retention

ADVANCED TURBINE ENGINE GAS GENERATOR (ATEGG)

OBJECTIVES

FUNCTIONALLY DEMONSTRATE AND ASSESS INNOVATIVE CORE ENGINE CONCEPTS (COMPRESSORS, COMBUSTORS, TURBINES)

VALIDATE THE 'TOOLS AND RULES' (PERFORMANCE, LIFE, SUPPORTABILITY, COST) OF ENGINE DESIGN AND OWNERSHIP

FINANCIAL ($M)

87	88	89	90	91	92
27.8	30.0	32.3	39.5	37.3	38.1

% HPTET DEDICATED

87	88	89	90	91	92
38	78	94	100	100	100

ATEGG IS COMBINED CYCLE USABLE

MILESTONES

WOUND COMPOSITE WHEEL	87
HPTET COMPOSITE SPACER/WHEEL	88
3D AERO-STRUCTURE INTERF	89
COMPOSITE ROTOR COMPRESSOR	90
ADV HPTET TURBINE TEST	91
STOICHIOMETRIC CORE DESIGN	92

ATEGG-MAJOR FY86 ACCOMPLISHMENTS

FLOWPATH

ADA PROGRAMMED FUEL CONTROL

'CORE DRIVEN' FAN

LARGE BLISKS/DRUM ROTORS

ATFE PLUS 250°F TURBINE TEMPERATURE

HIGHEST EVER FILM EFFECTIVENESS

125% ATFE CORE POWER VALUE

A.R.T. HP VANES

HIGH SHEAR FUEL NOZZLES

WAVY WALL COMBUSTOR

HPTET INITIAL AERODYNAMICS

INTEGRATED LONG RANGE PLAN

FULL ATFE LIFE CAPABILITY

STRUCTURES

30,000 PLUS TAC CYCLES ON MAJOR CORE COMPONENTS

QUANTIFIED ACCEL/DECEL EFFECTS ON HOT SECTION HARDWARE

CERAMIC BLADE OUTER AIR SEALS TESTED

QUANTIFICATION OF HPT NOZZLE/BLADE LIFE MODELS (LCF PLUS O/E)

TWO-PIECE PRECISION CAST TURBINE BLADING

ADVANCED PROPULSION SUBSYSTEM INTEGRATION (APSI) - The Aircraft Propulsion Subsystem Integration (APSI) Program is responsible for developing advanced propulsion system design tools and concepts to ensure a timely low risk application to future aircraft. The APSI program complements the ATEGG program in providing the functional demonstration of new design technologies necessary to assure propulsion and airframe compatibility in contributing to the attainment of future aircraft system advanced performance objectives. The program scope includes the following: the demonstration of design methods and tools for system responsive components related to inlets, fans, fan turbines, augmentors, controls, and exhaust nozzles; the overall integration and substantiation of these design capabilities through the integration of the APSI components with the basic ATEGG in technology demonstrator engine test vehicles; the development of reduced cost design techniques; and the definition of improved inlet/engine/exhaust system installation design criteria and propulsion structural assessment techniques. The APSI program accomplishes these broad range efforts through development and systematic refinement of analytical design tools which help assess and predict the performance of new technologies.

Current projects include efforts at both airframe and engine manufacturers. The following is a list of some specific features of technology by components.

Component Technology

Advanced Fans	Composite Structures Blisk Designs Mixed Flow Aerodynamics
Advanced Low Pressure Turbines	Lean-Bowed Stators Uncooled High Temp Airfoils Shroudless Tips Damage Tolerant Disk Counter-Rotating Speeds
Advanced Augmentors	Wall Flame Holders Integral Flameholder/Spraybar High Temperature Rise Lamilloy Liners Short Length
Advanced Nozzles	Axisymmetric/Thrust Reversing Composite Structures High Temperature Materials STOL Enhancement
Engine/Inlet Compatibility	Survivability Features
Controls	Improved Reliability/Electronics Fault Tolerant Designs Lightweight Designs Integrated Airframe/Engine Controls

AIRCRAFT PROPULSION SUBSYSTEMS INTEGRATION (APSI)

OBJECTIVE

DEVELOP/FUNCTIONALLY DEMONSTRATE ADVANCED TURBINE ENGINE TECH

- COMPONENTS – FANS, TURBINES, AUGMENTORS, NOZZLES, CONTROLS
- TECHNOLOGY DEMONSTRATORS – AIRCRAFT, MISSILE & HIGH MACH
- PROPULSION INTE–OBSERVABLES

PROVIDE COMPETITIVE/AFFORDABLE/ SUPPORTABLE DESIGN DEV OPTIONS

FUNDING ($M)

FY87	FY88	FY89	FY90	FY91	FY92
30.2	30.7	33.0	41.6	52.4	59.2

%HPTET DEDICATED

FY87	FY88	FY89	FY90	FY91	FY92
24	61	79	96	100	100

%COMBINED CYCLE

FY87	FY88	FY89	FY90	FY91	FY92
-	-	-	9	26	31

MILESTONES

AEDC/ASTF JTDE OPER TEST	1/87
FAULT TOLERANT ELECTRONIC ENGINE CONTROL	1/88
UNIQUE MISSILE ENG TECH DEMO	3/88
JTDE DEMONSTRATOR	
– INITIAL HPTE/HI MACH TECH	3/91
– STOVL/VSTOL TECHNOLOGIES	1/92

APSI – MAJOR FY 86 ACCOMPLISHMENTS

- COUNTER–ROTATING VANELESS LPT CONCEPT PROVEN
  - NEW AERO DESIGN MODEL VALIDATED
  - CAVITY DESIGN/SEAL IMPROVEMENTS DEFINED
- DEDICATED LIFE ASSESSMENT (OVER 6000 TAC CYCLES) COMPLETED ON CRITICAL NEW TECHNOLOGIES
  - 'FLOATWALL' COMBUSTOR– –PIN FIN, 'RAINBOW' MAT'LS/ATCHMTS
  - TURBINE– –'RAINBOW' HPT & LPT VANES/BLADES, PREFLAWED DISK
  - ADVANCED DUAL ELECTRONIC ENGINE CONTROL
  - VARIABLE AREA MIXING PLANE
  - LAMILLOY AUGMENTOR LINER/C-C NOZZLE PARTS
- LOW ASPECT RATIO FAN DURABILITY ASSESSMENT
  - DISTORTION TOLERANCE DATA FOR SURVIVABLE INSTALLATION
  - CRF ASSESSMENT EXCELLENT – MAJOR IMPROVEMENT IN DATA BASE

AEROSPACE POWER TECHNOLOGY

This project supports development and thermal management of solar power, fuel cells, batteries, hydraulics, and power conversion, conditioning and transmission devices for both space and flight vehicle applications. These analytical and experimental efforts form a balanced, board power subsystem technology base. Current goals include increased power output, decreased weight and volume, decreased vulnerability, increased life and reliability, and increased environmental tolerance for future systems.

FY86 Program: Design completion of a high temperature Variable Speed Constant Frequency electrical generator system, demonstration of high temperature capacitors and demonstration of a hot gas auxiliary power unit high temperature starter motor.

FY87 Planned Program: The fault tolerant aircraft electrical system research and development will continue toward demonstration in FY 1988. Application of Very High Speed Integrated Circuitry (VHSIC) technology to the electrical system to improve reliability and power density will be initiated. The low profile hydraulic actuator program for thin wing aircraft will be continued. *A high temperature hydraulic seal program will be initiated.

1988 Planned Program: The fault tolerant electrical system program will be completed. The VHSIC insertion into aircraft electrical system program will be continued. The low profile actuator program will be completed. The high temperature hydraulic seal program will be continued.

AIRCRAFT POWER TECHNOLOGY GOALS

1. 8000 PSI Nonflammable Hydraulic System
2. High Reliability Generator System
3. Fault Tolerant Electrical Power
4. Advanced Lightweight Auxiliary Power Unit
5. Low Maintenance Batteries

PROJECT FORECAST II REVELEANCY

1. PS-01 Intratheater VSTOL Transport Aircraft
2. PS-03 Multi-Role Global Range Aircraft
3. PS-04 Supersonic VSTOL Tactical Aircraft
4. PS-06 Hypersonic Interceptor Aircraft
5. PS-07 Special Operations Aircraft

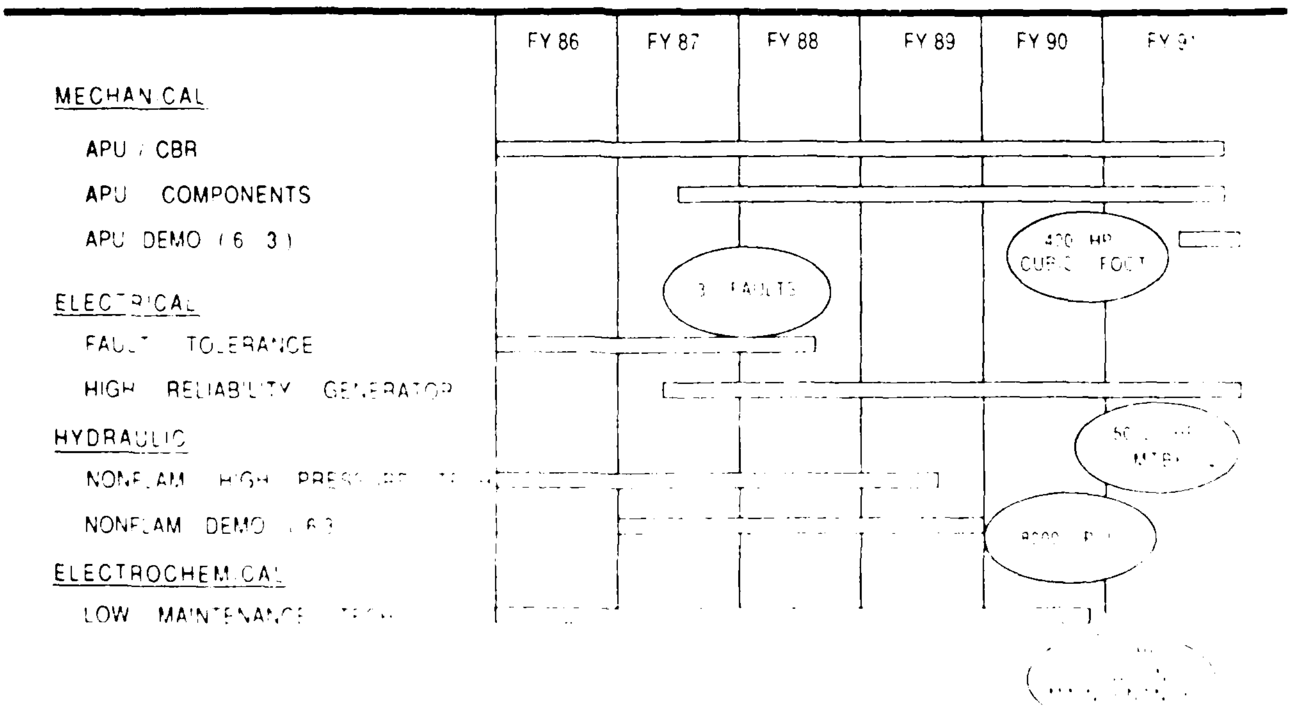
AIRCRAFT POWER TECHNOLOGY GOALS

- O 8000 PSI NONFLAMMABLE HYDRAULIC SYSTEM
- O HIGH RELIABILITY GENERATOR SYSTEM
- O FAULT TOLERANT ELECTRICAL POWER
- O ADVANCED LIGHTWEIGHT AUXILIARY POWER UNIT
- O LOW MAINTENANCE BATTERIES

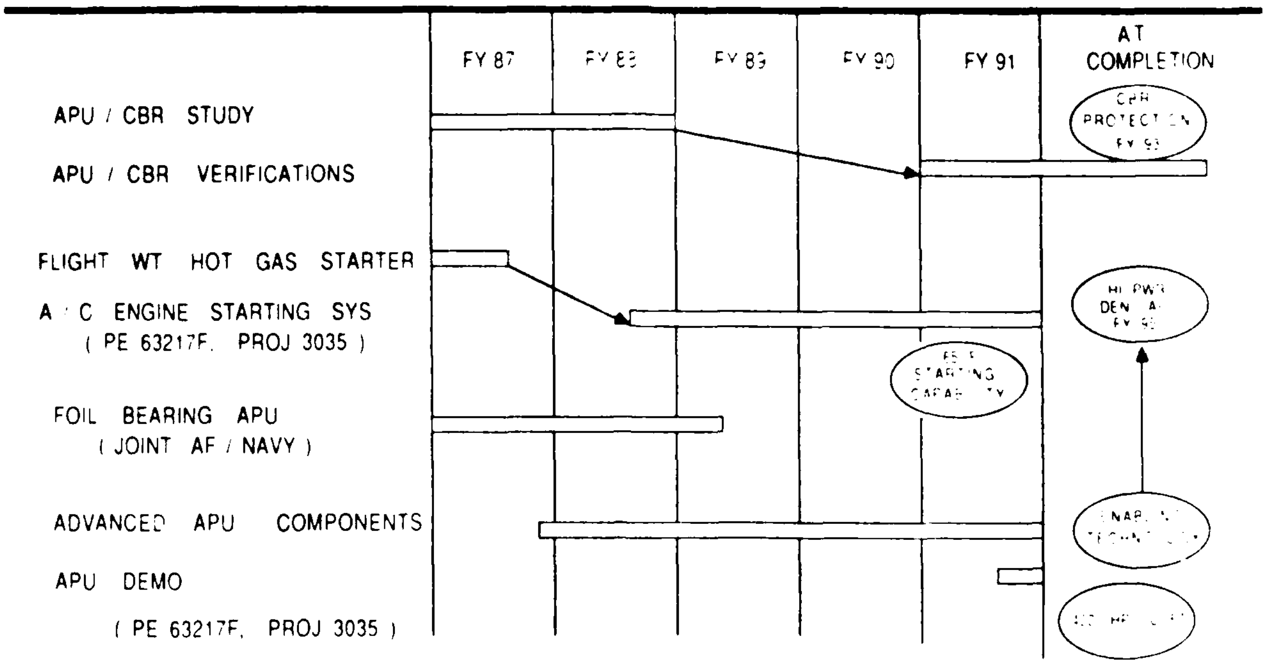
PROJECT FORECAST II REVELANCY

- O PS - 01 INTRATHEATER VSTOL TRANSPORT AIRCRAFT
- O PS - 03 MULTI ROLE GLOBAL RANGE AIRCRAFT
- O PS - 04 SUPERSONIC VSTOL TACTICAL AIRCRAFT
- O PS - 06 HYPERSONIC INTERCEPTOR AIRCRAFT
- O PS - 07 SPECIAL OPERATIONS AIRCRAFT

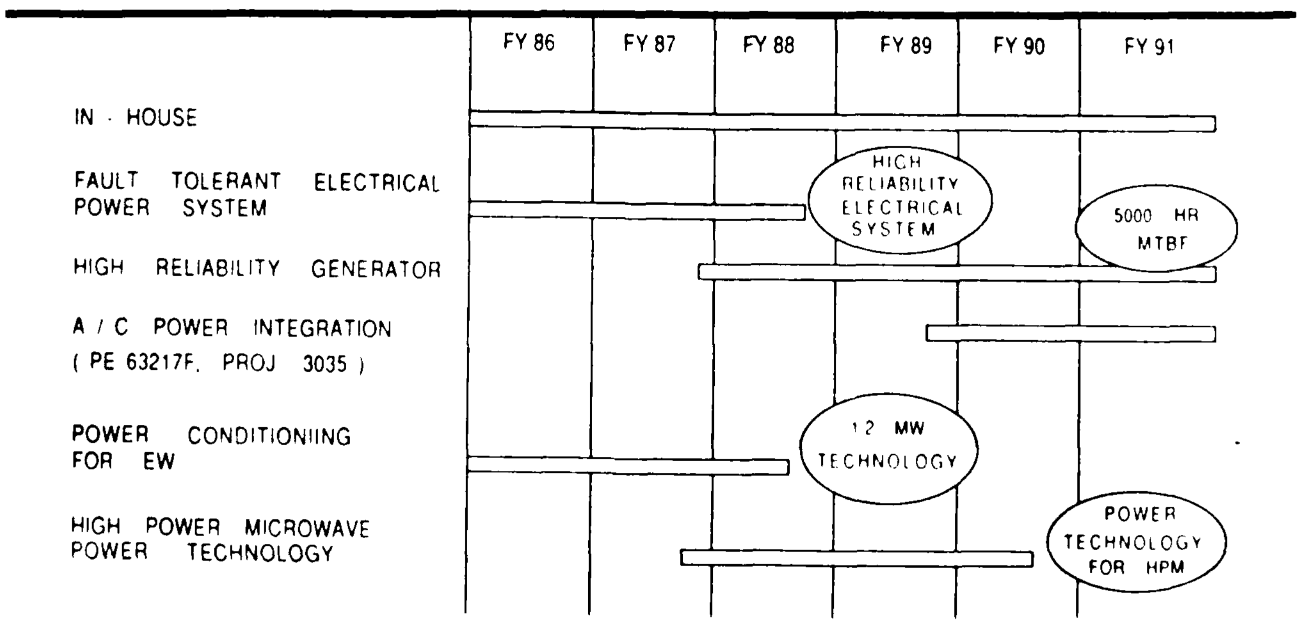
AIRCRAFT POWER ROADMAP



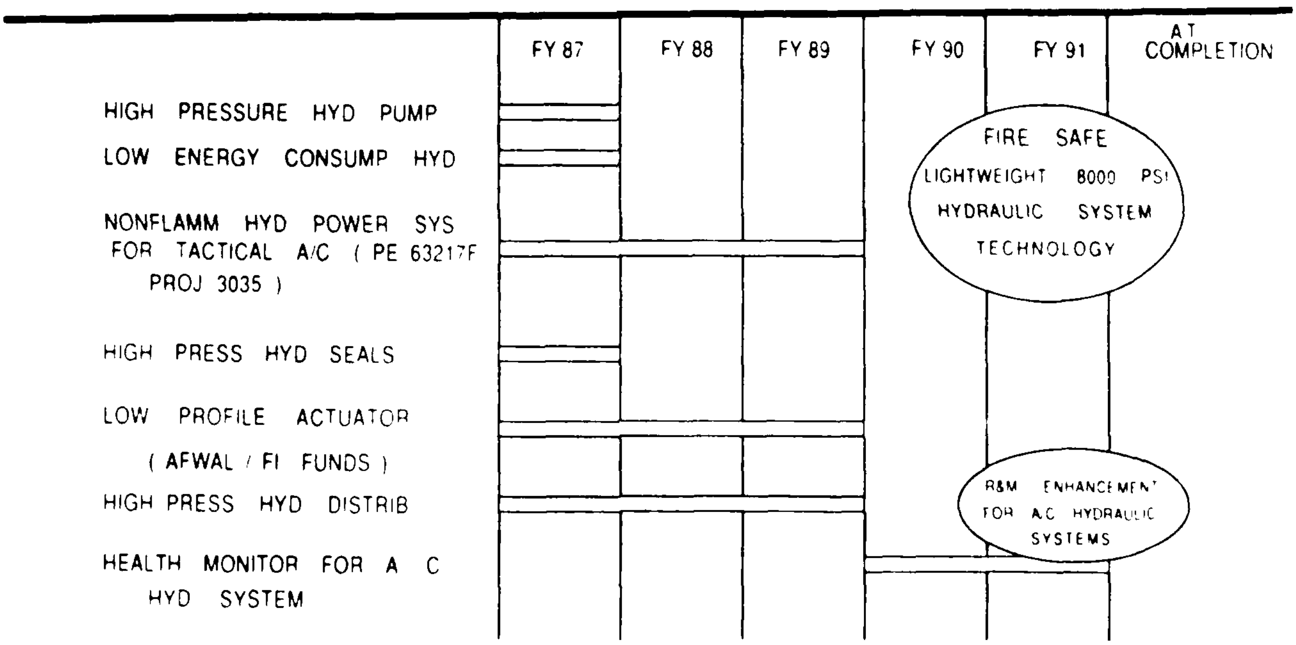
AIRCRAFT POWER ROADMAP
MECHANICAL



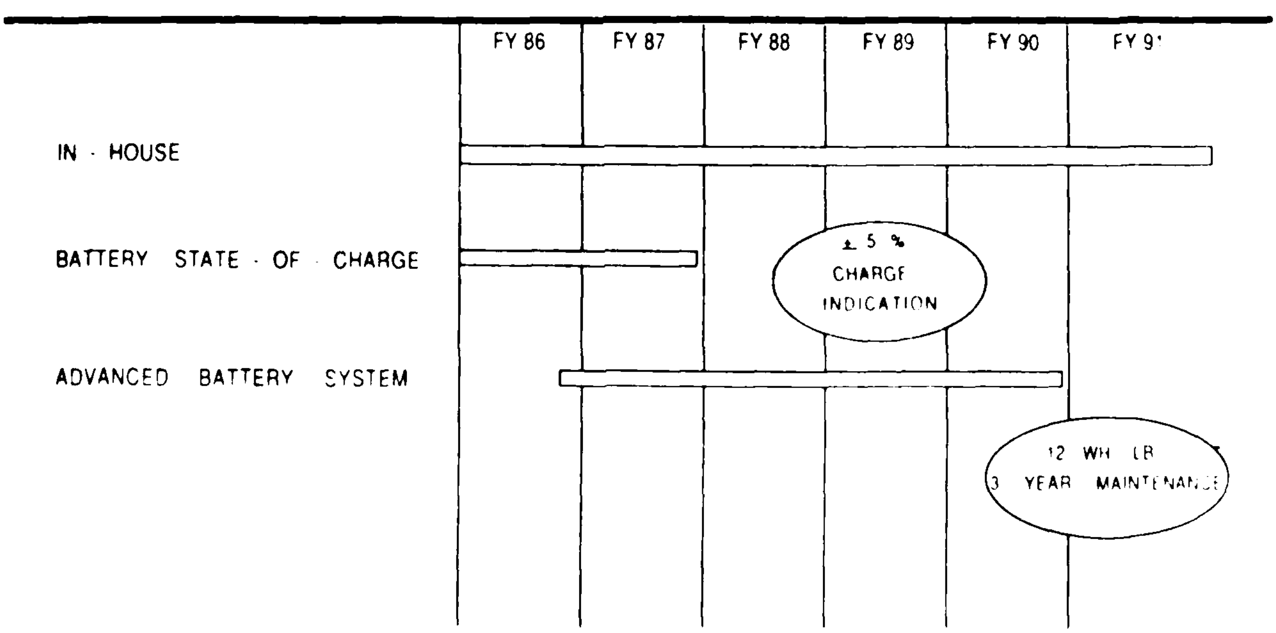
AIRCRAFT POWER ROADMAP
ELECTRICAL



AIRCRAFT POWER ROADMAP HYDRAULIC



AIRCRAFT POWER ROADMAP ELECTROCHEMICAL



AIRCRAFT FUELS, LUBRICATION, AND FIRE PROTECTION TECHNOLOGY

The purpose of this project is to provide: (a) improved Air Force fuels and the understanding of fuel/system capabilities required to support present and future airbreathing engine powered weapon systems, (b) lubricants, lubrication techniques, condition monitoring techniques, and lubrication system components (bearings, seals, dampers) to satisfy the stringent requirements of future aerospace weapon systems, and (c) advanced fire and explosion hazard characterization methodology, fire prevention and containment measures, hazard detection, and active and passive protection system to satisfy flight vehicle combat survivability and operational safety requirements. Additionally, this project supports other Air Force commands in resolving operational system problems and coordinates and controls the research, development, test, and evaluation (RDT&E) of Air Force fuels, lubricants, and associated specialty fluid products for airbreathing propulsion and power systems. The project is divided into five major emphasis areas: aviation fuels, missile fuels, lubricants, bearings, and fire protection.

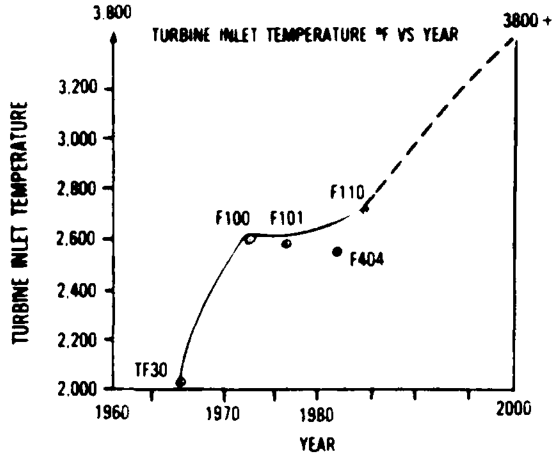
FY 1986 Program: Fuel development and evaluation program are continuing with the characterization of high density fuels produced from a variety of sources as well as potential new fuels, such as endothermics for hypersonic systems. The laminar flame speeds of two candidates endothermic fuels are being determined. A breadboard carbon slurry fuel system for long-range cruise missiles has been fabricated and will be demonstrated. A ramjet boron solid fuel, which has 70% more volumetric energy than the current baseline hydrocarbon fuels, has been developed. Research efforts have been redirected toward development of an improved lubricant with 400 F bulk oil capability to meet Advanced Tactical Fighter (ATF) engine requirements. The service evaluation of the Portable Wear Metal Analyzer was successfully completed and the instrument has been transitioned to AFLC for eventual use by the mobility forces. A new technique has been demonstrated for measurement of life remaining in used turbine engine lubricants. Life testing for an improved corrosion resistant bearing material (MRC2001) was successfully completed. An analytical effort will be initiated to realistically define High Performance Turbine Engine Technologies (HPTET) lubricant and lubrication system mechanical component requirements.

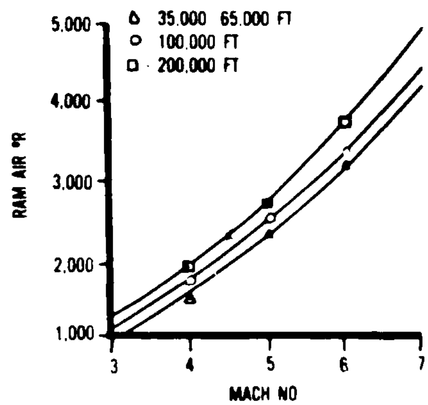
FY 1987 Planned Program: Preliminary efforts to determine characteristics of high-energy endothermic fuels for hypersonic vehicle applications will be started. Properties of interest include heat sink capacity, specific heat, heat of vaporization, thermal stability and combustion. In addition, a fuel system simulator, which was designed and fabricated under contract, will be used in-house to evaluate the effects of high density fuels on fuel system components such as fuel pumps, heat exchangers and fuel controls. Standardization activities and support requirements will continue to be met. The specification for a high-temperature, all-weather (-60 F to 400 F) lubricant to meet ATF engine requirements will be finalized. Major efforts will be reoriented to address Forecast II lubricant needs such as HPTET, Combined Cycle Engine, and the Advanced Aerospace Plane. New efforts to fully define the capabilities of candidate lubricants for HPTET will be initiated. Joint development programs with the Navy on improved life bearings and counter-rotating bearings and seals will be completed. Development of dry lubricated bearings (solid, lubricated,and foil) for limited life small engines

and Auxiliary Power Units (APUs) will continue. An effort will be initiated to establish the feasibility of magnetic bearings for use as a mainshaft support for turbine engines. The evaluation of a small-scale advanced air separation module for On-Board Inert Gas Generator System will be completed; all other efforts in the fire protection area will be phased out.

FY 1988 Planned Program: High heat sink fuel studies will be continued to determine the potential of using such fuels in hypersonic applications. Advanced high energy chemicals will be evaluated for potential use in advanced weapon systems. A four-year contractual program will be initiated to measure the laminar flame speeds, ignition delay times and other combustion parameters of advanced fuels. These programs are needed by system designers to design fuel systems and combustors for advanced systems. Fuels and lubricant standardization and support requirements will continue. Efforts will continue to characterize the capabilities of advanced lubricants to meet Forecast II and JAFE requirements. The -60 F to 400F lubricant will be released for procurement late in FY 1988. Development efforts on small soild lubricated bearings will continue. The analytical effort to identify lubrication needs for High Performance Turbine Engine Technologies (HPTET) will be completed and will provide the basis for defining specific programs to address specific Forecast II requirements. Small-scale HPTET lubrication system simulator development effort will be initiated to evaluate small volumes of experimental lubricants along with advanced bearing and seal development programs including a magnetic bearing feasibility and demonstration effort.

IMPACT OF ENGINE OPERATIONAL ENVIRONMENT ON ADVANCED LUBRICATION SYSTEMS



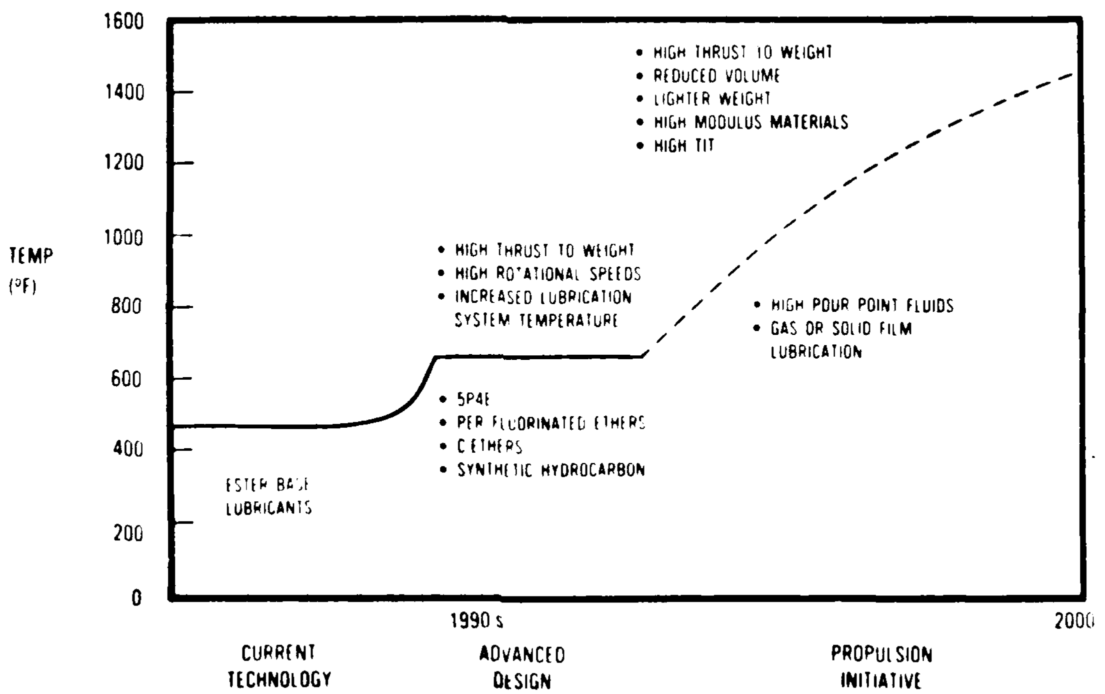


LUBRICANT SYSTEM IMPACT: INCREASED LUBRICATION SYSTEM TEMPERATURES

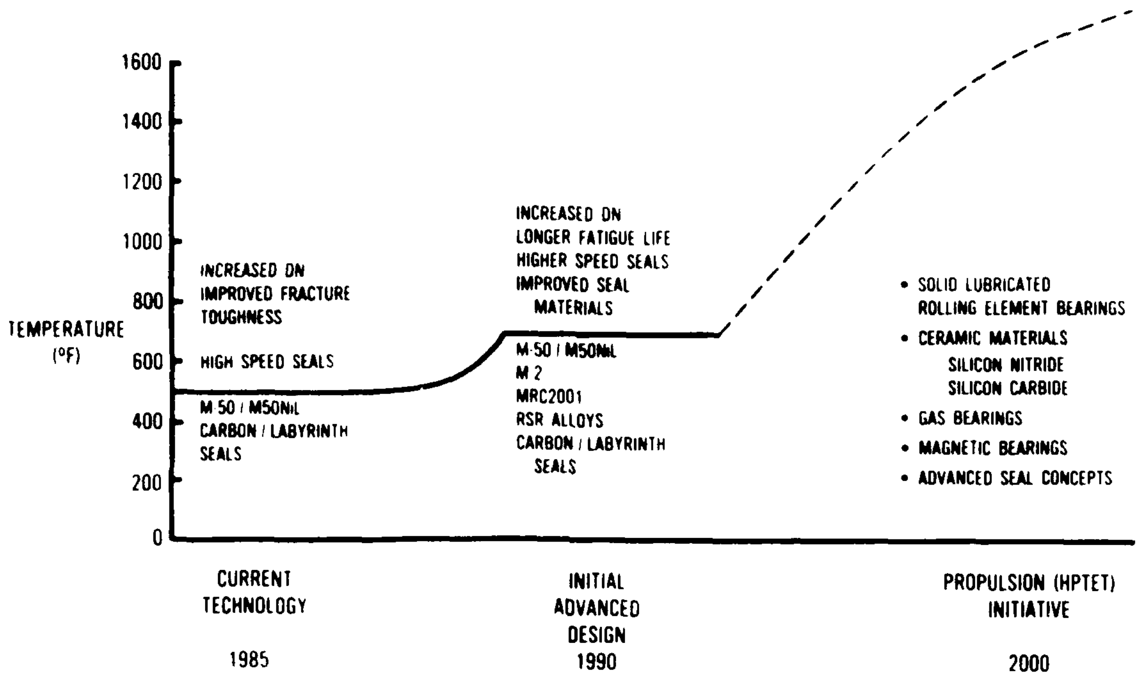
NEED:

- HIGHER TEMPERATURE LUBRICANTS
  - LIQUID
  - SOLID
- HIGHER TEMPERATURE LUBRICATION SYSTEM COMPONENTS
  - BEARINGS / SEALS / GEARS / DAMPERS
- INCREASED COOLING REQUIREMENT
  - BLEED AIR
  - HIGH EFFICIENCY FUEL / OIL COOLERS
  - HIGH EFFICIENCY COOLING TECHNIQUES

ADVANCED LUBRICANT REQUIREMENTS

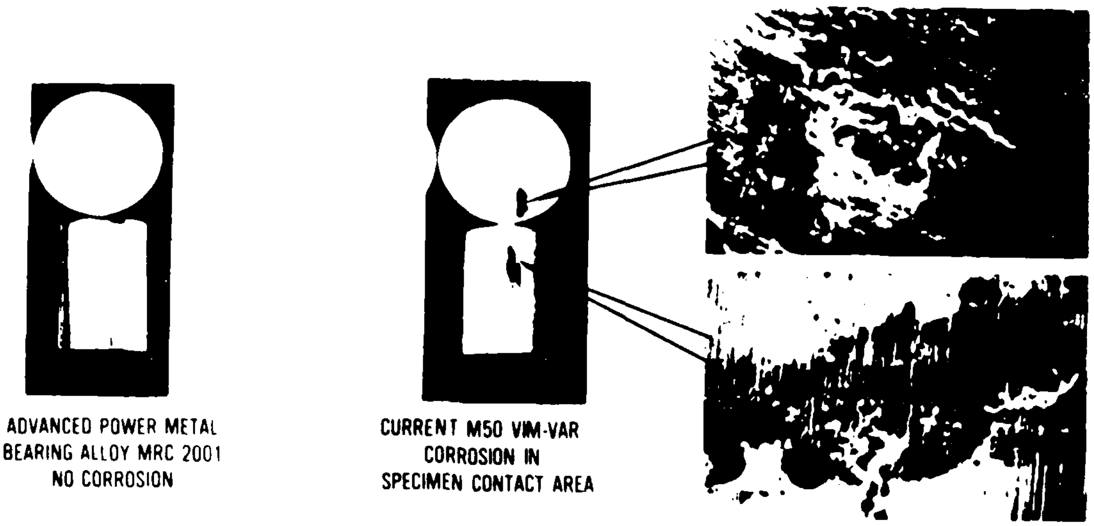


ADVANCED LUBRICATION SYSTEM REQUIREMENTS



TURBINE ENGINE BEARINGS

IMPROVED CORROSION RESISTANCE DEMONSTRATED



ADVANCED POWER METAL BEARING ALLOY MRC 2001 NO CORROSION

CURRENT M50 VIM-VAR CORROSION IN SPECIMEN CONTACT AREA

STAINED AND PITTED SURFACES

300X

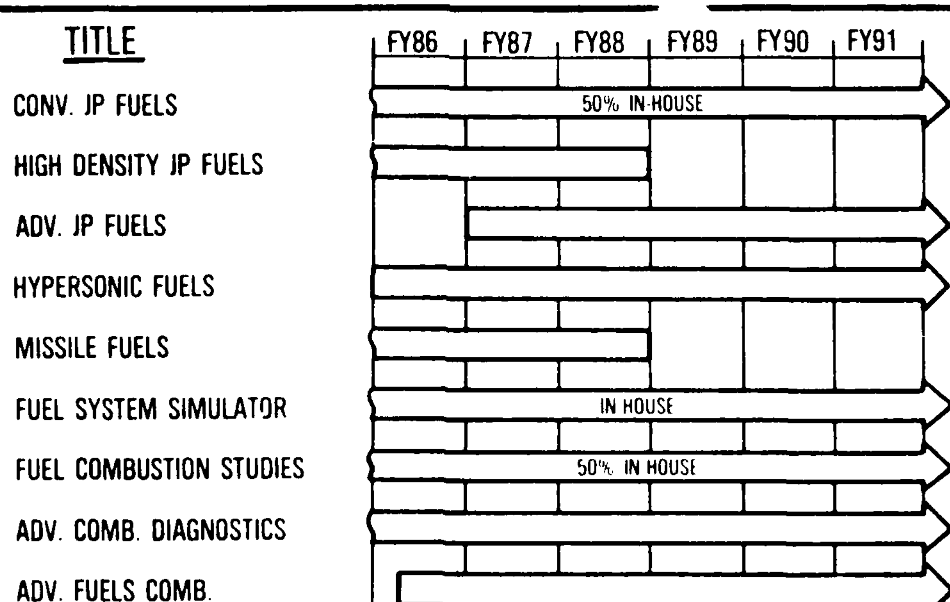
ELIMINATION OF CORROSION AS A CAUSE OF BEARING REJECTION WILL SAVE THE AIR FORCE $3-4M / YEAR

HIGH DENSITY AVIATION TURBINE FUELS

TYPICAL PROPERTIES

	JP-4	JP-5	JP-8	JP-8X
DENSITY, KG/M^3	764	818	800	872
BOILING RANGE, °F	150-480	370-500	350-520	350-520
HEAT OF COMBUSTION				
BTU/LB	18,700	18,400	18,500	18,300
BTU/GAL	120,000	126,000	124,000	135,000
HYDROGEN CONTENT, WT%	14.4	13.7	13.8	13.3
VISCOSITY, CENTISTOKES ā				
-40°F	2.8	11.0	10.0	14.0
0	1.0	4.2	3.8	4.4
40°F	1.4	2.2	2.0	2.4
FLASHPOINT, °F	-22	140	128	128
FREEZING POINT, °F	-75	-45	-50	-80

AERO-PROPULSION FUELS R & D



TOTAL FUNDING:

($ MILLIONS)		FY86	FY87	FY88	FY89	FY90	FY91
	6.1	0.5	0.5	0.5	0.5	0.5	0.5
	6.2	3.2	4.0	3.9	3.5	3.8	4.2
	6.3	6.5	2.4	3.0	-	-	-

UNMANNED VEHICLES

ADVANCED PROPULSION TECHNOLOGY

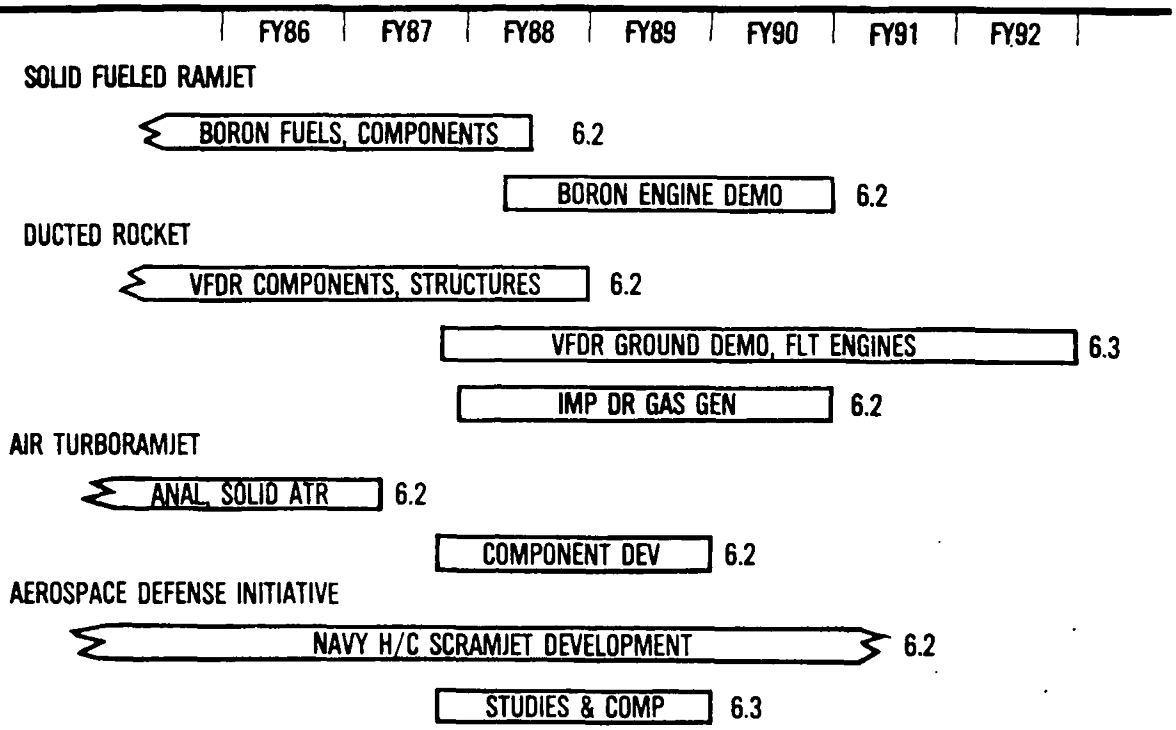
This project develops airbreathing propulsion technology for future high speed aircraft, launch vehicles, and missiles. Application of the technologies under development include: Combined Cycle Engines including Turboramjets (TRJs) and Air Turboramjets (ATRs) for aircraft and space vehicles; Scramjets (Supersonic Combustion Ramjets) for launch vehicles and hypersonic aircraft; ducted ramjets, solid fuel ramjets and ATRs for air-to-surface, air-to-air and other long range missile applications. The inclusion of propulsion technology for high speed aircraft and launch vehicles is a major change and results in a deemphasis of missile technology.

a. FY 1986 Program: A several year program to develop swirl combustion technology was completed thus allowing a threefold shortening of ramjet burners. All basic work was completed on solid fueled Variable Flow Ducted Ramjet technology. This major milestone allows transition to Advanced Development and, ultimately, the development of air-to-air missiles with twice the capability of today's best. Breakthroughs were achieved in Boron fuel formulation and Boron fuel combustion efficiencies for solid fuel ramjets thus allowing a 50% or better range improvement over conventional liquid fueled ramjet missiles. Major efforts in advanced missile structures and aero configured missile designs were begun. Studies of composite engines and scramjet engines were initiated.

b. FY 1987 Program: Major efforts on turboramjets, air turboramjets, and scramjets will be initiated. The objectives of this work are to dramatically expand the operational envelope for future aircraft (by several Mach numbers) and to provide order of magnitude reduction in launch costs. Analysis results will be available during this period and critical component experiments will have begun. Development of advanced structures for ramjet missile engines will allow a 30% reduction in missile engine weight. This advance plus integration of the engine in an aerodynamically configured missile design will allow revolutionary improvements in missile effectiveness. Programs to exploit Boron fuels will be emphasized in the Solid Fuel Ramjet area.

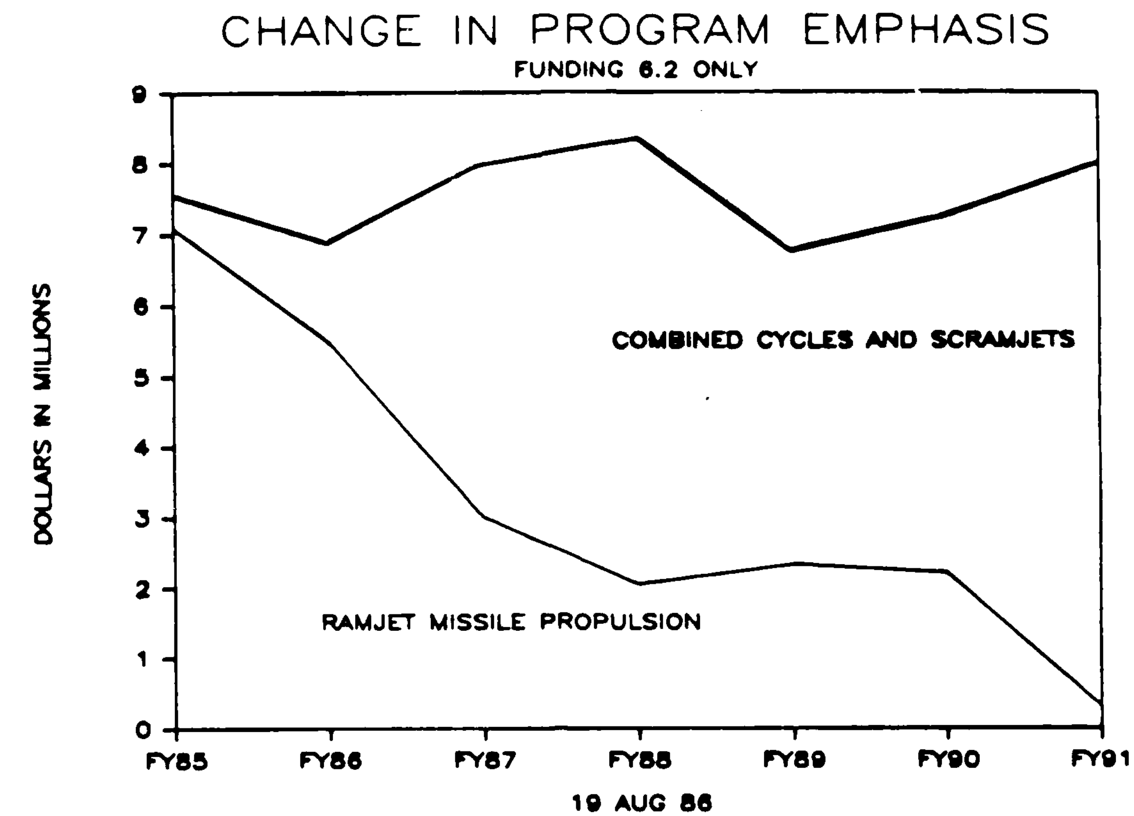
c. FY 1988 Program: Tests of Scramjet engine critical components will provide a basis for future engine development efforts and vehicle designs. Turboramjet and air turboramjet designs will be intiated based on the completion of analysis and initial component work. Advanced structures work for missile engines will be completed and transitioned to Advanced Development or application. A new generation of ducted ramjet technology will be initiated to allow greater altitude excursions (greater throttle ratio) and use of higher energy fuels.

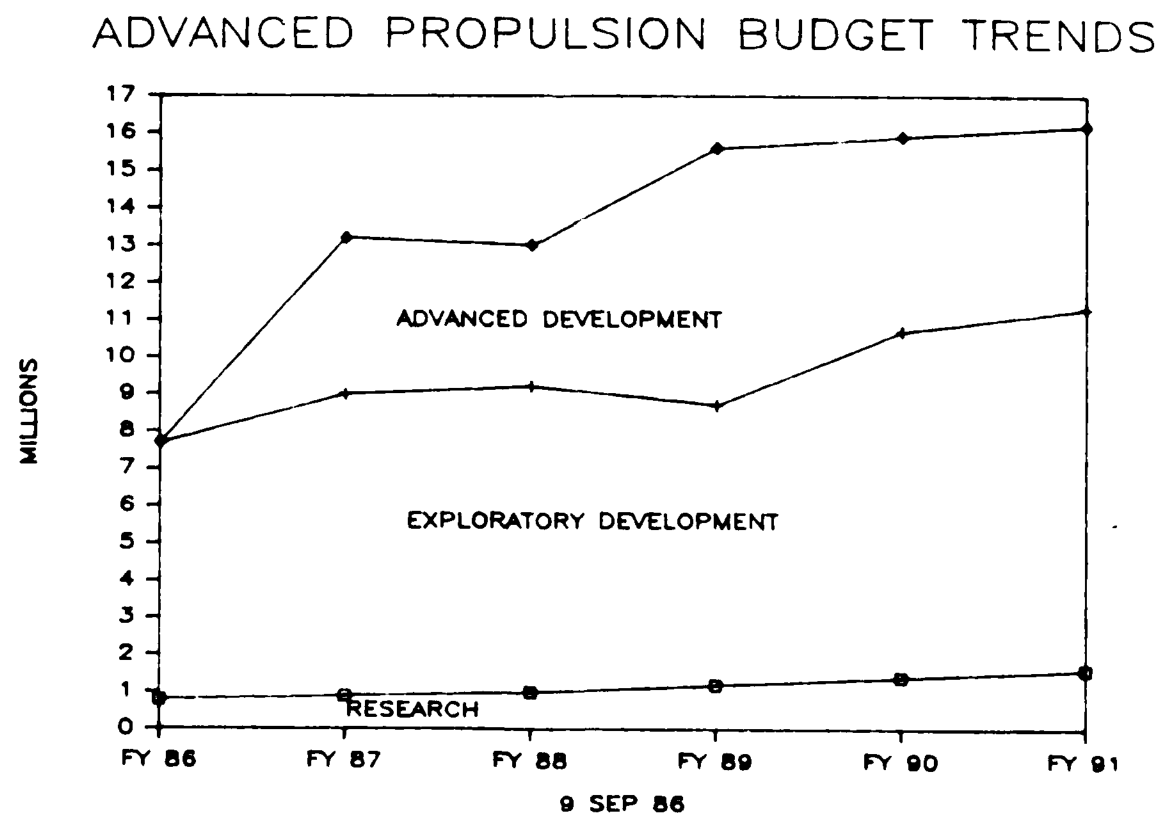
MISSILE RELATED PROGRAMS



FORECAST II RELATIONSHIPS

PT-4	COMBINED CYCLE ENGINE
PS-8	AUTONOMOUS ANTI-ARMOR WEAPONS
PS-9	AUTONOMOUS HIGH VALUE TARGET WEAPONS
PS-12	LONG RANGE AIR-TO-AIR MISSILES
PS-14	HYPERVELOCITY WEAPONS
PS-18	LONG RANGE BOOST-GLIDE VEHICLE
PS-47	MULTI-ROLE CONVENTIONAL WEAPON


CHANGE IN PROGRAM EMPHASIS
FUNDING 6.2 ONLY
DOLLARS IN MILLIONS
9
8
7
6
5
4
3
2
1
0
COMBINED CYCLES AND SCRAMJETS
RAMJET MISSILE PROPULSION
FY85
FY86
FY87
FY88
FY89
FY90
FY91
19 AUG 86


ADVANCED PROPULSION BUDGET TRENDS
MILLIONS
17
16
15
14
13
12
11
10
9
8
7
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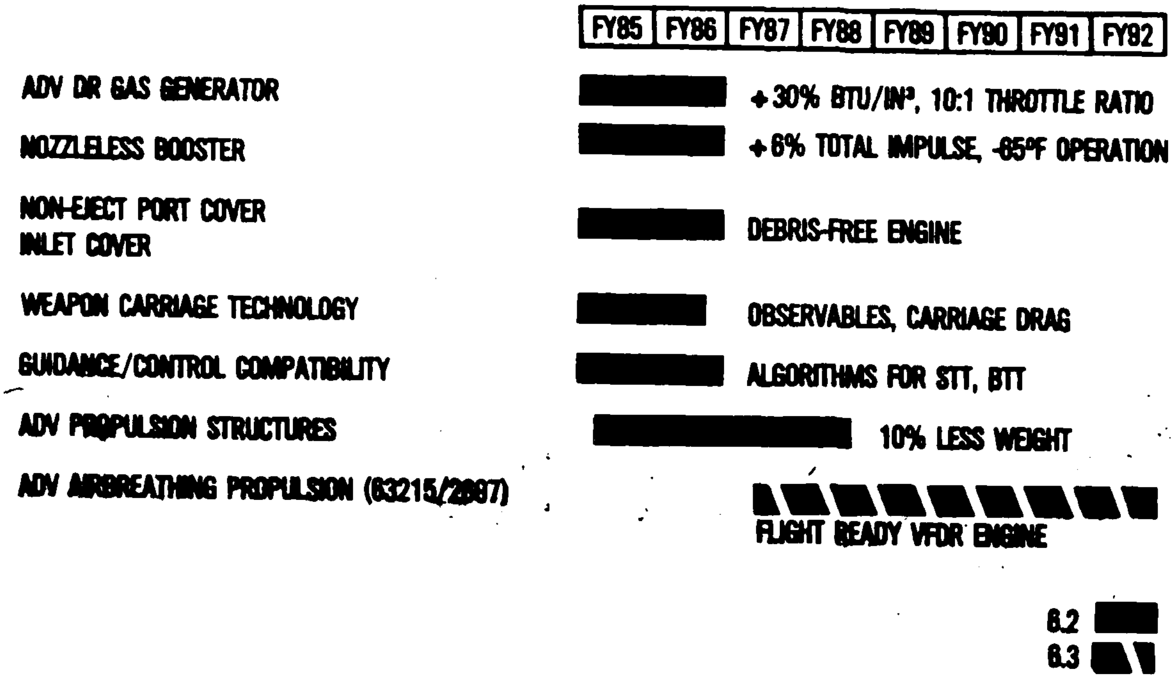
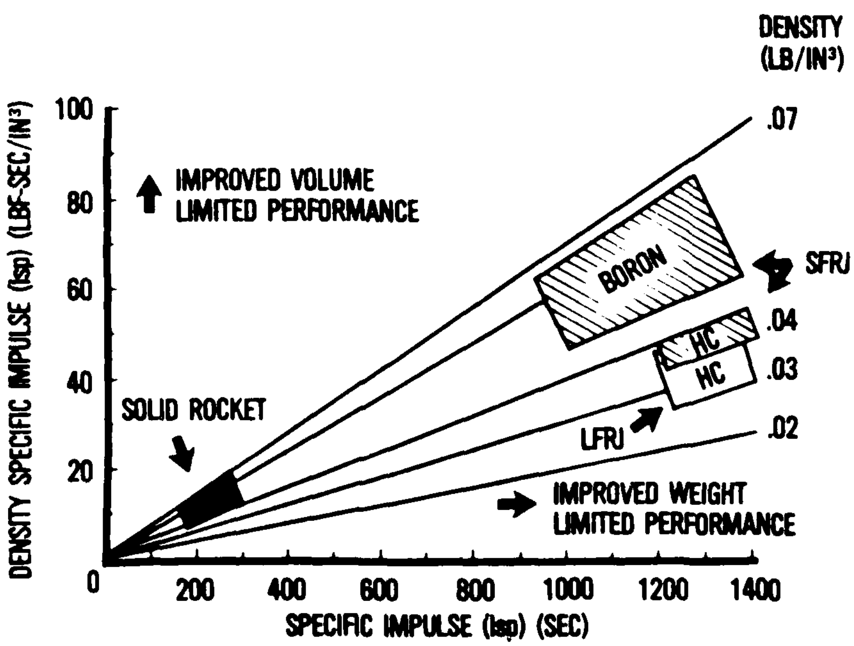
5
4
3
2
1
0
ADVANCED DEVELOPMENT
EXPLORATORY DEVELOPMENT
RESEARCH
FY 86
FY 87
FY 88
FY 89
FY 90
FY 91
9 SEP 86

DUCTED ROCKET RAMJET PROGRAMS



SFRJ FUEL TRENDS



AIR TURBORAMJET - COMPONENT TECHNOLOGY (6.2)

OBJECTIVE: • VALIDATE CRITICAL ATR COMPONENT AND SUBSYSTEM PERFORMANCE IN PREPARATION FOR AN ATR ENGINE DEMONSTRATOR PROGRAM

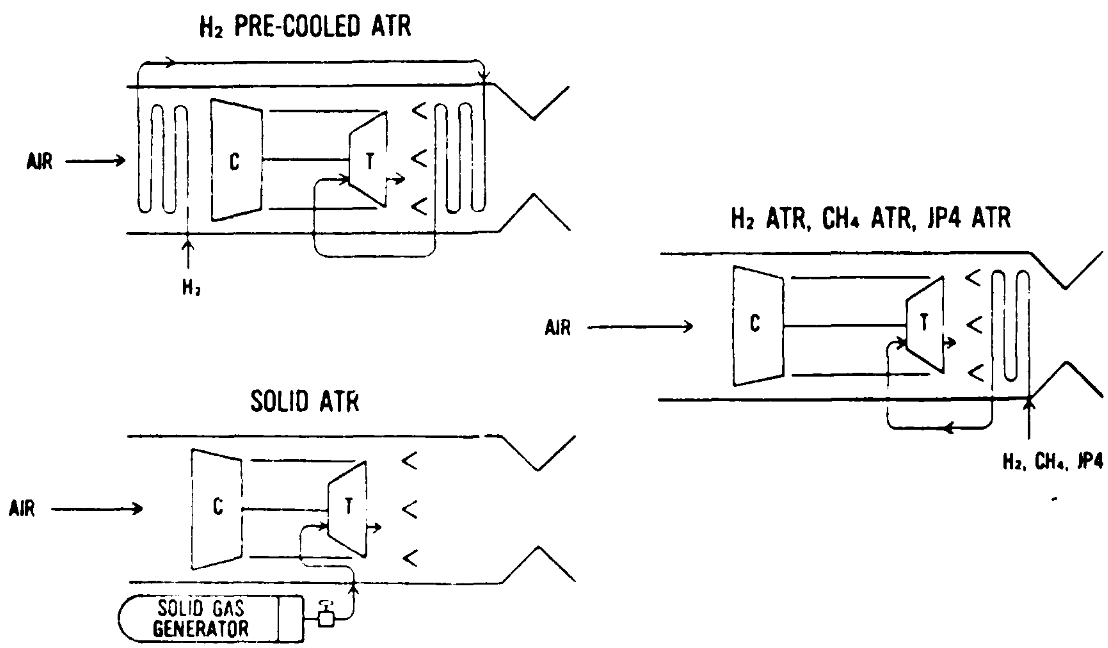
APPROACH: • MACH 0 TO 6-8 SPEED RANGE

- APPLICATIONS: ADVANCED MISSILES: OTHER HIGH SPEED VEHICLES (MANNED AND UNMANNED)
- DEVELOP TECHNOLOGY GENERIC TO ANY MISSION, AS WELL AS MISSION CRITICAL TECHNOLOGY
  - COMPONENT DESIGN & EVALUATION
  - OVERALL ENGINE DESIGN & PERFORMANCE

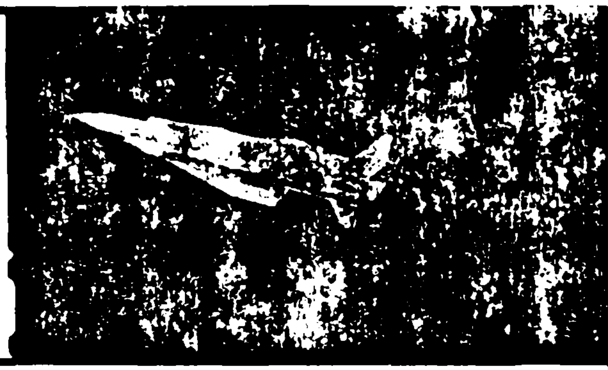
KEY MILESTONES:

- ANTICIPATED PRDA RELEASE - WEEK OF 6 OCT 86
- ANTICIPATED CONTRACT START - FEB 87
- COMPLETE PROGRAM - FEB 90

AIR-TURBORAMJET CYCLES



AIR DEFENSE INITIATIVE
SUPERSONIC CRUISE MISSILE
PROPULSION (RAMJET/SCRAMJET)



PHASE I OBJECTIVE

- DEFINE ENGINE/AIRFRAME CONFIGURATION AND SUBSYSTEMS TO MEET MISSION REQUIREMENTS
- DEMONSTRATE INLET
- DEMONSTRATE ENGINE THERMAL PROTECTION/MATERIALS
- ESTABLISH ENGINE/AIRFRAME FLIGHT TEST PLAN (PHASE II)

PAYOFF/MILITARY SIGNIFICANCE

- FLEXIBLE LAUNCH CAPABILITY
  - GROUND LAUNCH
    - FAST RESPONSE
  - AIR LAUNCH
    - EXTEND CAPABILTY OF AIR PATROL
- DEFEAT BOTH CRUISE MISSILES AND LAUNCH AIRCRAFT
- TRAJECTORY FLEXIBILITY
- HIGH INTERCEPT MANEUVERABILITY

TECHNOLOGY CHALLENGES

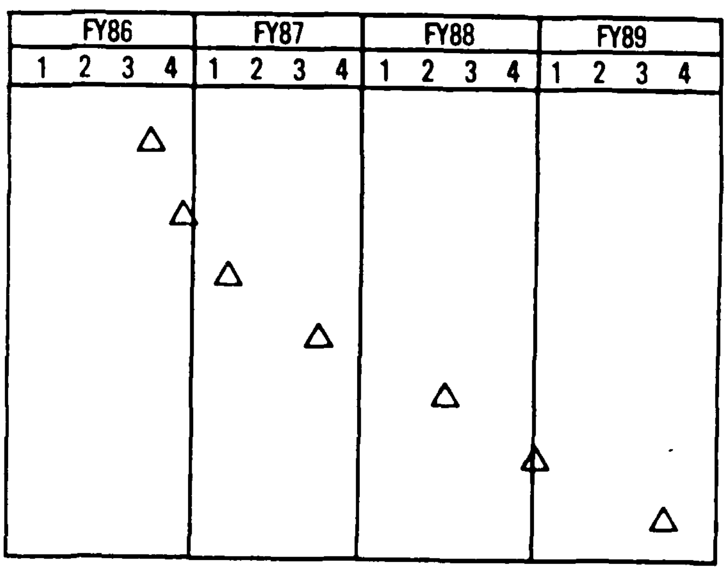
- SUPERSONIC COMBUSTION
- INLET/ENGINE/AIRFRAME INTEGRATION
- MATERIALS/STRUCTURES

AIR DEFNSE INITIATIVE
SUPERSONIC CRUISE MISSILE
PROPULSION (RAMJET/SCRAMJET)

- KEY MILESTONES

PHASE I

- PRELIMINARY STUDIES (THREAT DEFINED, MISSION BRACKETED)
- TPP APPROVED AND RFP RELEASE
- PROGRAM START
- MISSION DEFINITION
- ENGINE/AIRFRAME CONFIG, PHASE II PLAN
- INLET DEMONSTRATION
- THERMAL PROTECTION/MATERIALS DEMO



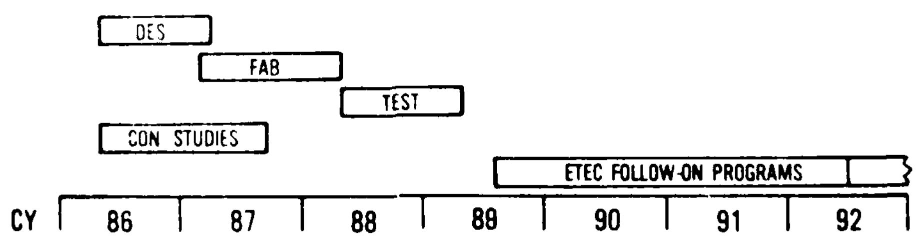
PROCUREMENT APPROACH
- TASK ASSIGNMENT CONTRACTS FOR STUDIES
- MODIFY EXISTING CONTRACTS FOR TESTING

ETEC PROGRAM OBJECTIVE

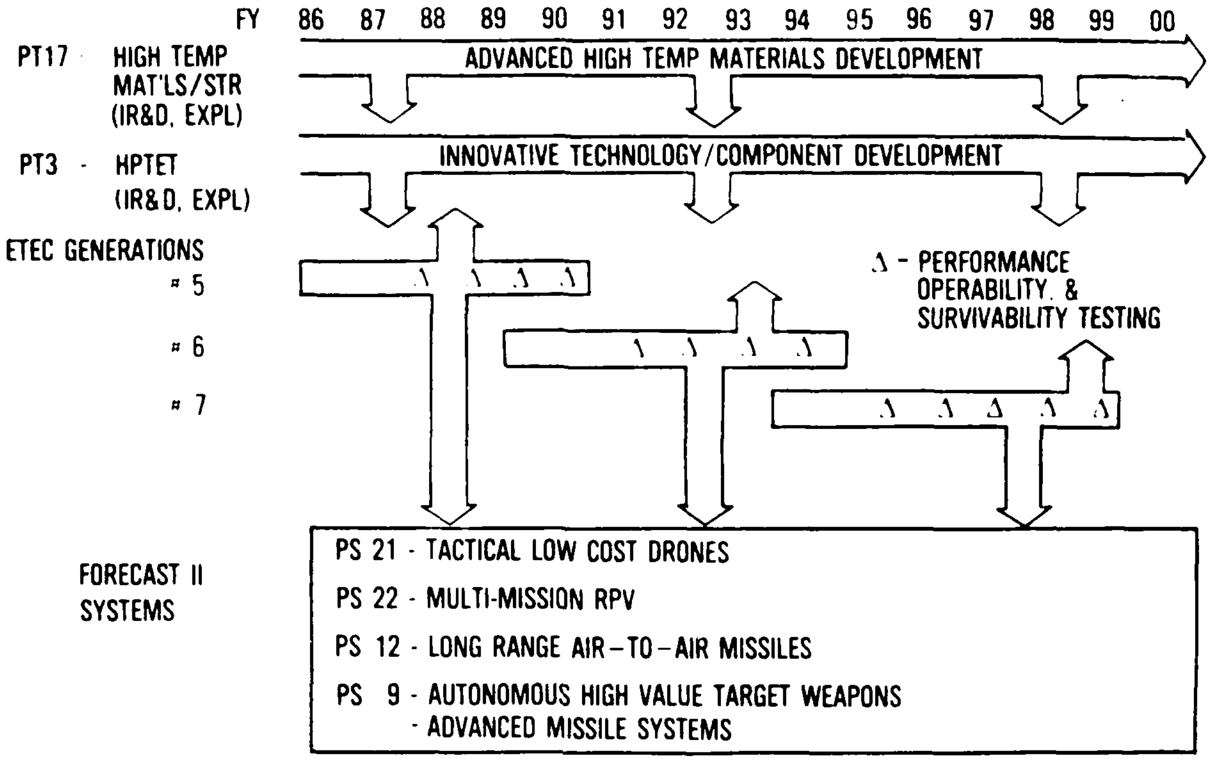
- PROVIDE FUNCTIONAL DEMONSTRATION OF UNIQUE HIGH PAYOFF COMPONENT TECHNOLOGIES IN EXPERIMENTAL ENGINE DEMONSTRATORS
    - LOWER COST
    - HIGHER PERFORMANCE
    - IMPROVED SURVIVABILITY
- PROVIDE TECHNOLOGY BASE FOR A BROAD RANGE OF MISSILE APPLICATIONS
    - SUBSONIC TACTICAL
    - SUBSONIC STRATEGIC
    - SUPERSONIC TACTICAL/STRATEGIC

ETEC PROGRAM APPROACH/SCHEDULE

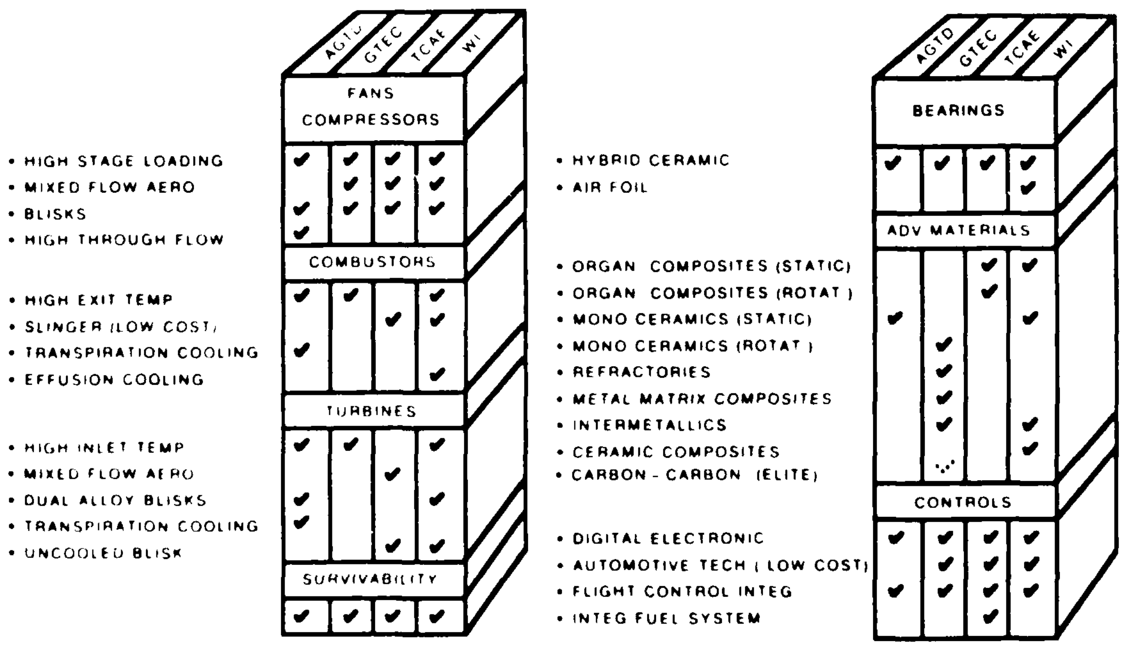
- HARDWARE DEMONSTRATION TASK
    - DETAIL DESIGN
    - ACCELERATED COMPONENT DEVELOPMENT
    - HARDWARE FABRICATION, INSTRUMENTATION AND ASSEMBLY
    - DEMONSTRATOR TESTING
        - PERFORMANCE
        - OPERABILITY
        - SURVIVABILITY
- CONCEPT DEFINITION TASK
    - SELECTION OF MISSILE SYSTEM/MISSION REQUIREMENT
        - 1995-2005 IOC
    - ENGINE CONCEPT/CONFIGURATION DEFINITION
    - COMPARATIVE PROPULSION/MISSION ASSESSMENT
        - MISSILE GROSS WEIGHT, SIZE, RANGE, COST, FLEXIBILITY/SURVIVABILITY CAPABILITIES



ETEC TECHNOLOGY TRANSITION



ETEC ADVANCED TECHNOLOGIES



AEROSPACE POWER TECHNOLOGY

This project supports development and thermal management of solar power, fuel cells, batteries, hydraulics, and power conversion, conditioning and transmission devices for both space and flight vehicle applications. These analytical and experimental efforts form a balanced, broad power subsystem technology base. Current goals include increased power output, decreased weight and volume, decreased vulnerability, increased life and reliability, and increased environmental tolerance for future systems.

FY 1986 Program: Exploratory development of low cost, reliable, and rechargeable lighium battery will be completed.

FY 1987 Planned Program: The sodium sulfur space battery and the high power density missile battery programs will be continued.

FY 1988 Planned Program: The fault tolerant electrical system program will be completed. The high power density missile battery development will continue.

MISSILE POWER GOALS

Strategic

A. Onboard, 100 WH/LB, 300 W/LB, 10's of Minutes (Lithium Thionyl Chloride)
B. Silo Emergency Power, Lithium Rechargeable, 10 X Increase in Duration
C. Dynamic Power system (Cruise Missile), 250 W/LB, Hours

Tactical

1. Onboard, Lithium - Chlorine Thermal, 50 WH/LB, 10 KW/LB Minutes

Propulsion

1. Battery / Motor / Propellor, 10's of Horsepower

PROJECT FORECAST II REVELANCY

1. PS-05 High Altitude Long Endurance Unmanned A/C
2. PS-09 Autonomous High Value Target Weapons
3. PS-12 Long Range Air to Air Missiles
4. PS-14 Hypervelocity Weapons
5. PS-18 Long Range Boost Glide vehicle
6. PS-21 Tactical Low Cost Drones
7. PS-22 Multi-Mission Remotely Piloted Vehicles
8. PS-26 Direct Assent Anti-Satellite System (ASAT)

MISSILE POWER GOALS

STRATEGIC

- O ONBOARD. 100 WH / LB. 300 W / LB. 10 ' s OF MINUTES (LITHIUM - THIONYL CHLORIDE)
- * O SILO EMERGENCY POWER. LITHIUM RECHARGEABLE. 10 X INCREASE IN DURATION
- * O DYNAMIC POWER SYSTEM (CRUISE MISSILE). 250 W / LB. HOURS

TACTICAL

- O ONBOARD. LITHIUM - CHLORINE THERMAL. 50 WH / LB. 10 KW / LB MINUTES

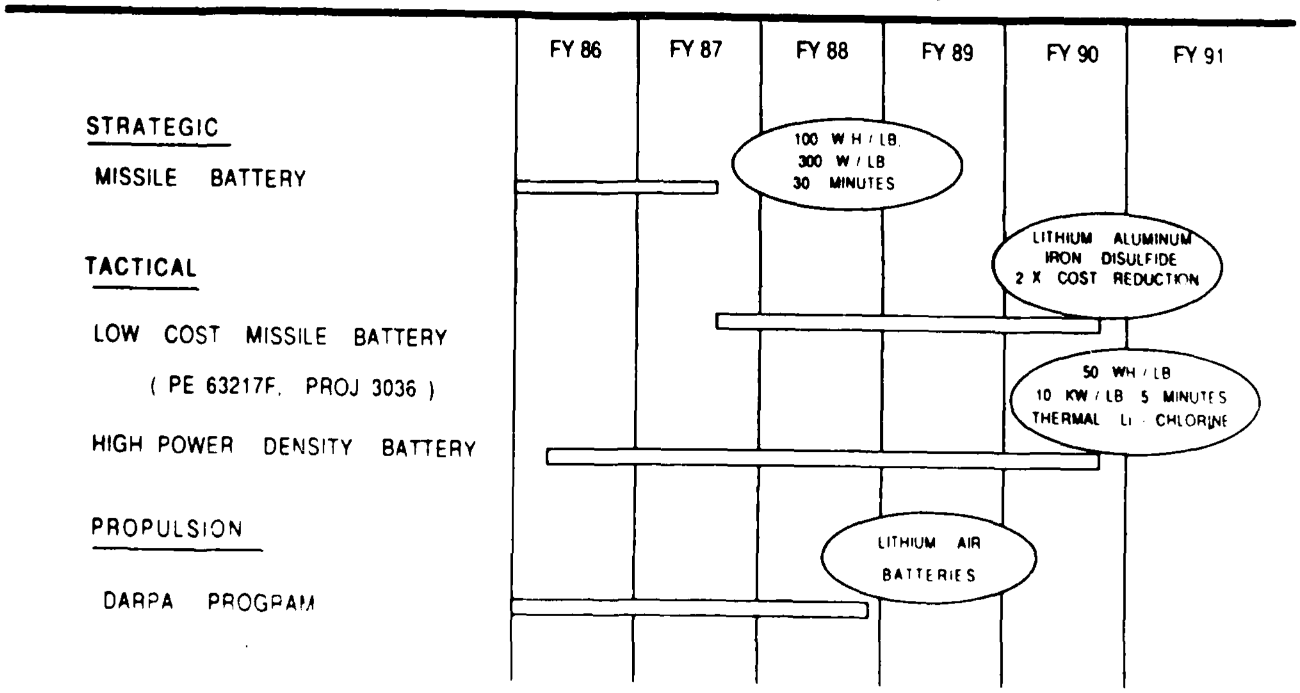
PROPULSION

- ** O BATTERY / MOTOR / PROPELLOR. 10 ' s OF HORSEPOWER

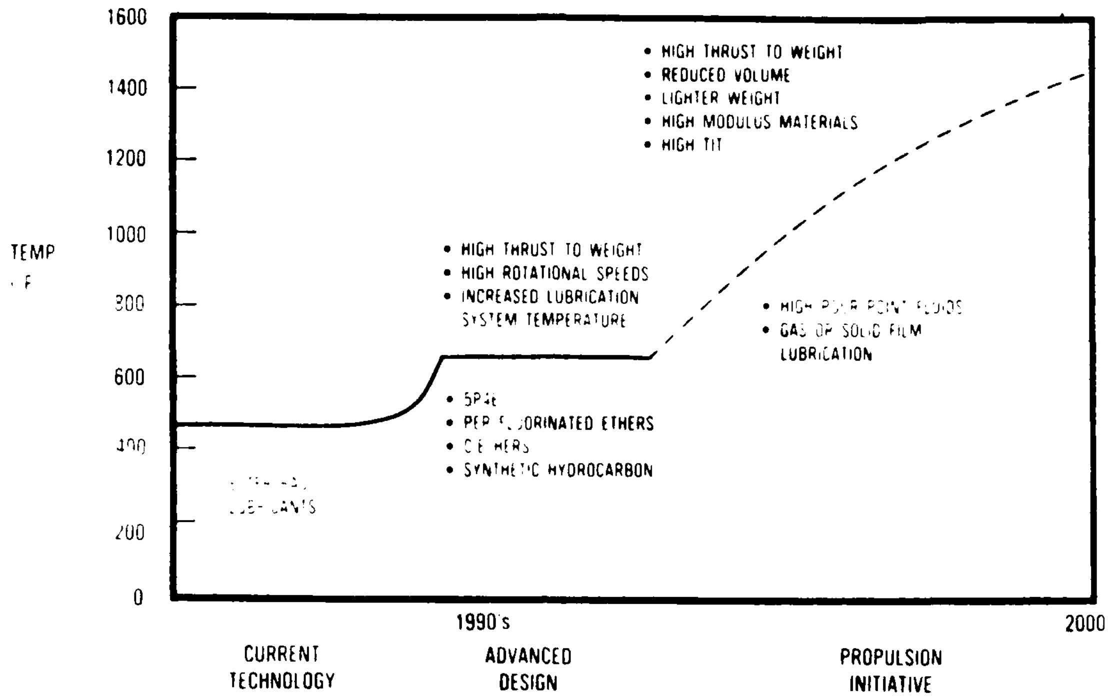
PROJECT FORECAST II REVELANCY

- O PS - 05 HIGH ALTITUDE LONG ENDURANCE UNMANNED A / C
- O PS - 09 AUTONOMOUS HIGH VALUE TARGET WEAPONS
- O PS - 12 LONG RANGE AIR TO AIR MISSILES
- O PS - 14 HYPERVELOCITY WEAPONS
- O PS - 18 LONG RANGE BOOST GLIDE VEHICLE
- O PS - 21 TACTICAL LOW COST DRONES
- O PS - 22 MULTI - MISSION REMOTELY PILOTED VEHICLES
- O PS - 26 DIRECT ASSENT ANTI - SATELLITE SYSTEM (ASAT)

MISSILE POWER (ELECTROCHEMICAL)



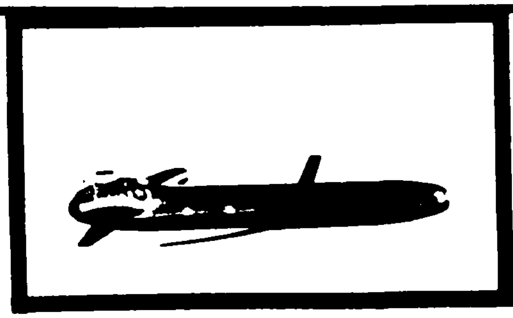
ADVANCED LUBRICANT REQUIREMENTS

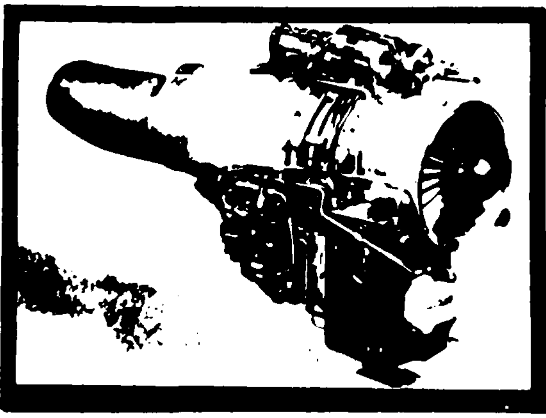


ADV. DRY LUBRICATED BRG / GEAR TECHNOLOGY FOR LIMITED LIFE ENGINE APPLICATIONS

GOALS:

- DRY LUBRICATED (SOLID AND / OR GAS) BEARING / GEAR TECHNOLOGY FOR ADVANCED CRUISE MISSILE ENGINES
  - SPEEDS - UP TO 2.5 X 10^6 DN
  - TEMPERATURES - UP TO 1500 °F





PAYOFFS:

- COMPLETE ELIMINATION OF LIQUID LUBRICATION SYSTEM
  - REDUCED WEIGHT AND COMPLEXITY
  - IMPROVED STORABILITY AND SURVIVABILITY
  - REQUIRED TECHNOLOGY FOR HIGH AND FAST MISSIONS

HYPERVELOCITY VEHICLES

ADVANCED AEROSPACE VEHICLES

Tomorrow's military aerospace vehicles, and demanding missions will generate an unprecedented set of technology requirements. Designers will be pressed to attain fully responsive enabling solutions to the challenges of performance, operations, logistics, and, especially, reduced costs. The conventional all-rocket approach, for earth-to-orbit missions, may be inadequate for the design of a true advanced aerospace vehicle. Further, regarding airbreathing propulsion, significant departure from strictly evolutionary engine development seems necessary for these acceleration/propulsion missions. Key elements involved include (1) acceleration (instead of cruise) emphasis, (2) combined cycle (airbreathing/rocket) engines, and (3) autonomous, operationally flexible, fully reusable vehicles. The advance needed involves total integration of airbreathing and rocket engine capabilities.

With few notable exceptions, earth-to-orbit launch vehicles (both actual hardware systems and study concepts) have used rocket propulsion. However, with the extremes of high performance, low operating costs, and wide mission profile flexibility, perceived as needed for future military aerospace vehicles, alternative propulsion approaches must be considered. In particular, there is a need to explore the advantages of advanced airbreathing propulsion systems in conjunction with rocket capabilities. The shift to airbreathing propulsion is warranted in view of its order-of-magnitude improvement in specific fuel consumption. This benefit results from using atmospheric, rather than tanked, oxidizer (as in the case of rockets). Although such advanced airbreathing engines represent a significant developmental challenge, the key technological ingredients, as well as applicable engine/vehicle design concepts, are available today. The Air Force Aero Propulsion Laboratory has initiated the study of advanced airbreathing systems for the earth-to-orbit acceleration mission. Concepts believed to be fully responsive to tomorrow's demanding vehicle/mission requirements are being systematically assessed.

Figure 21 depicts the broad expanse of airbreathing performance in terms of specific impulse (Isp). Two fuel bases are indicated: hydrocarbon and hydrogen. The superiority of hydrogen results largely from its high gravimetric heating value (2.8 times higher than that of hydrocarbon fuels). The very low molecular weight of hydrogen also contributes to its superior performance. The order-of-magnitude higher performance of airbreathing propulsion, as compared to rockets, is mainly a consequence of effectively using atmospheric oxygen instead of vehicle-tanked liquid oxygen (or other oxidizer).

For acceleration missions, airbreathing propulsion systems necessarily operate within altitude/Mach number "corridor" as shown in Figure 22. This is typically bounded on the high side by basic low-pressure combustion limits and insufficient thrust production. The lower limit approximates that "thermal thicket" where heat-transfer and internal duct-pressure limitations force the engine to be too heavy or overly complex, in terms of cooling and construction. The situation is similar to that of cruise-oriented conventional-engine operating regimes within this corridor. Traditionally, to increase speed

ELEMENTAL PROPULSION OPTIONS

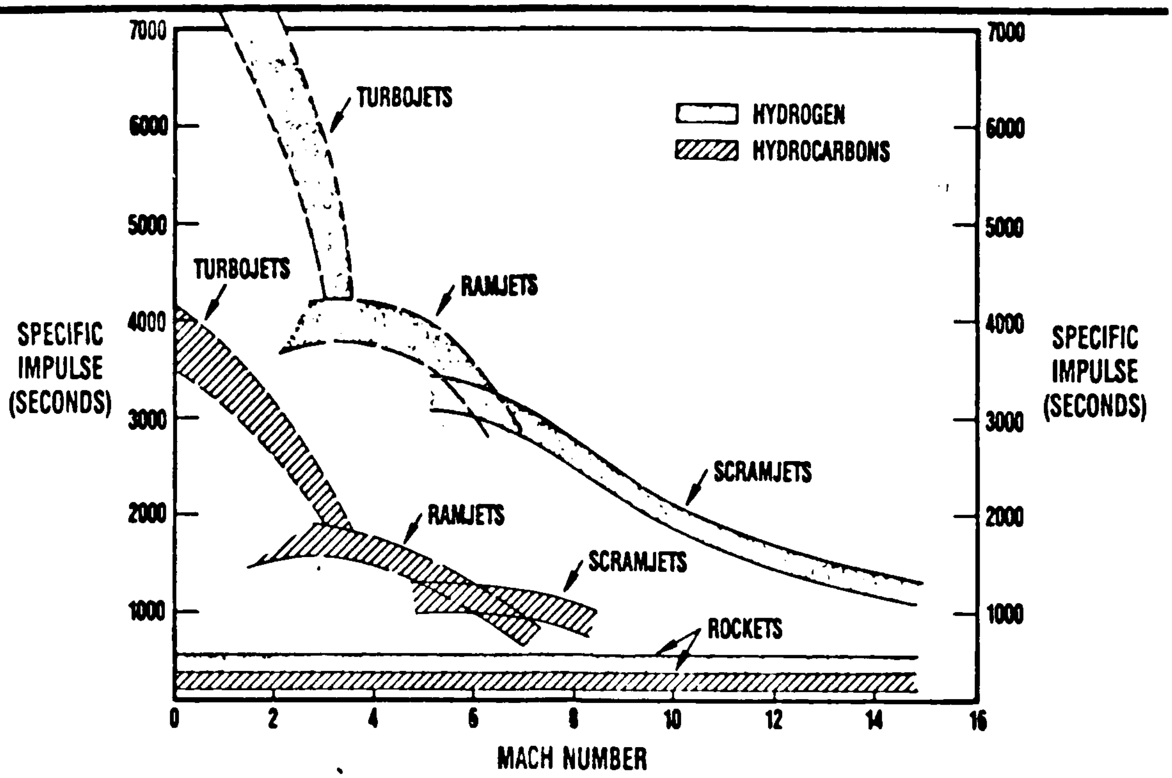


FIGURE 21

AIRBREATHING PROPULSION CORRIDOR

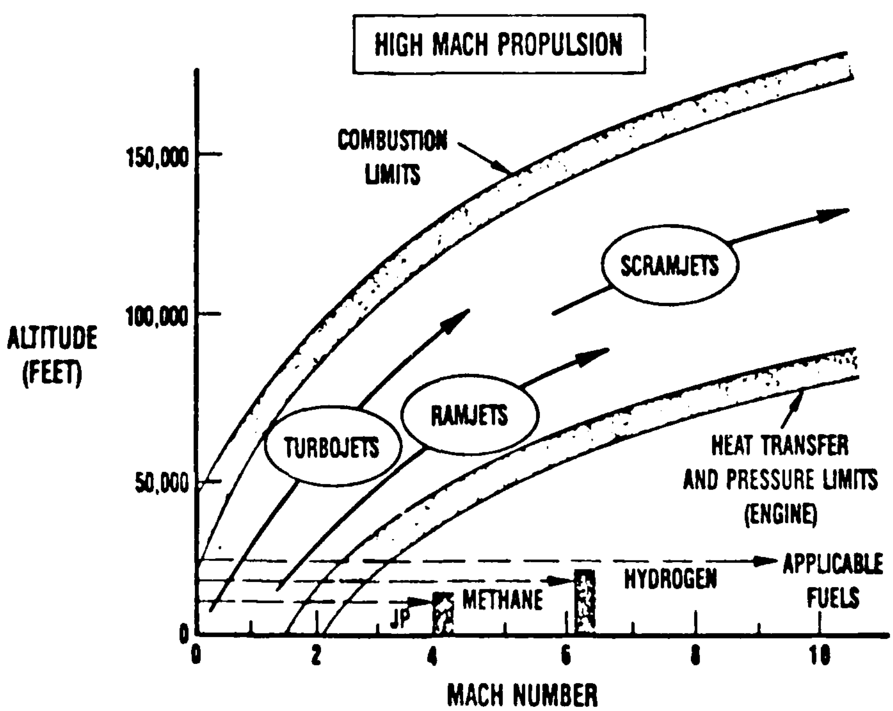
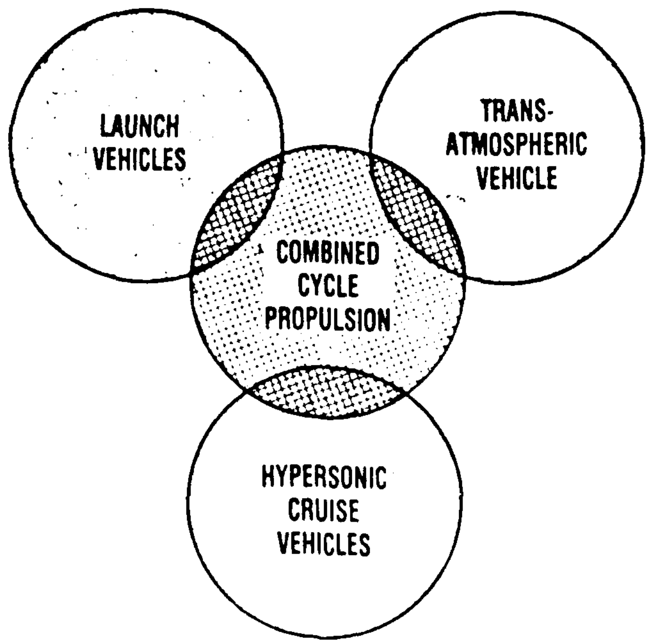
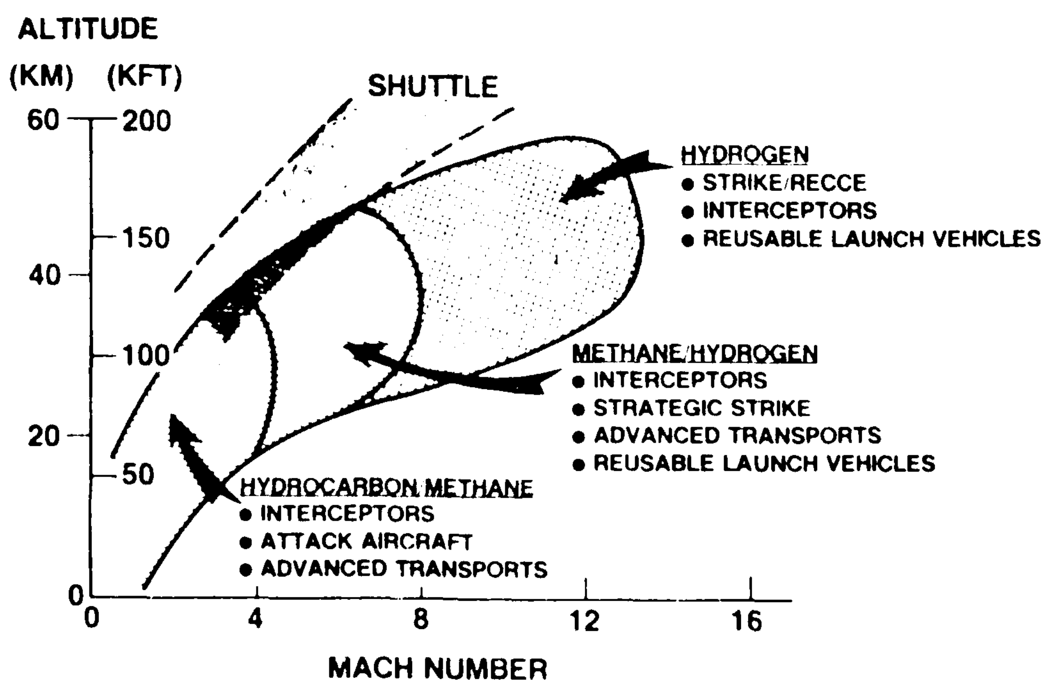


FIGURE 22

HYPERSONIC AEROSPACE VEHICLES



AIRBREATHING HYPERSONIC AIRCRAFT
— AERONAUTICAL APPLICATIONS —



TECHNOLOGY NEEDS

MATERIALS/STRUCTURES

- AIRFRAME MATERIALS
- AIRFRAME STRUCTURES
- CRYOGENIC TANKAGE
- PROPULSION SYSTEM STRUCTURES AND MATERIALS
- ENVIRONMENTAL LOADS AND DESIGN CRITERIA
- DISCIPLINARY/INTERDISCIPLINARY ANALYSIS AND OPTIMIZATION
- TEST REQUIREMENTS/FACILITIES

PROPULSION/POWER

- ETO COMBINED CYCLE PROPULSION SYSTEM
- PROPULSION/AIRFRAME INTEGRATION
- OTV PROPULSION SYSTEM
- FUEL CELL POWER SYSTEM
- HIGH ENERGY DENSITY BATTERY SYSTEM
- POWER MANAGEMENT SYSTEM

AEROTHERMODYNAMICS/FLIGHT MECHANICS

- COMPUTATIONAL FLUID DYNAMICS
- ASCENT AERODYNAMICS WITH PLUME
- INTERACTIONS
- AERODYNAMIC/AEROTHERMODYNAMIC DATA BASE
- AERODYNAMIC MODELING
- GROUND BASED TEST FACILITIES
- FLIGHT TESTS
- FLIGHT ENVIRONMENT DEFINITION

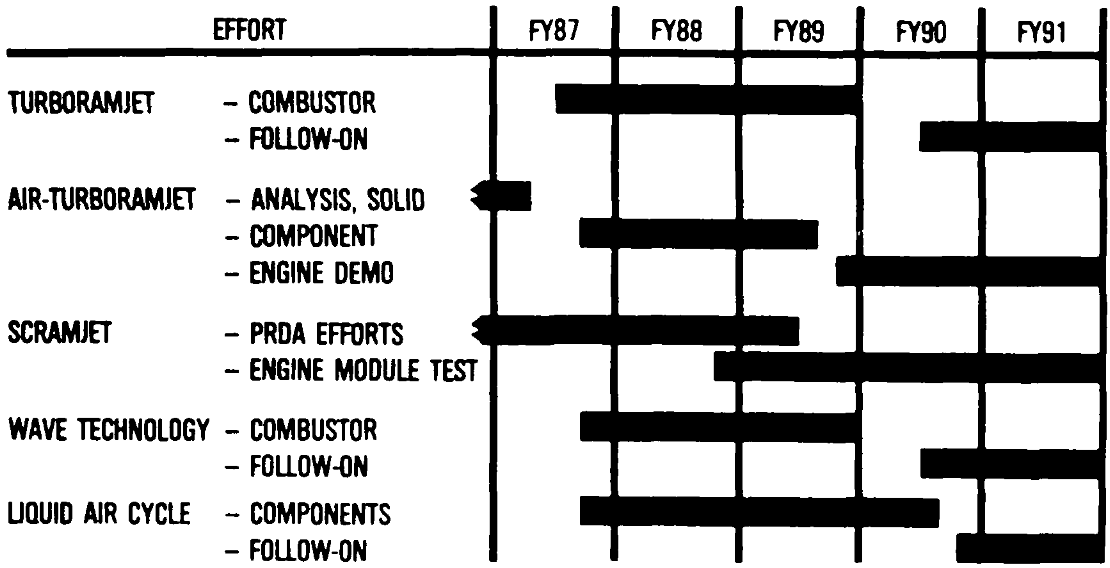
AVIONICS/SOFTWARE/AUTOMATION

- NAVIGATION AND COMMUNICATIONS
- AVIONICS SUBSYSTEMS
- FLIGHT SYSTEMS MANAGEMENT
- SYSTEMS ARCHITECTURE, INTEGRATION, AND MODELING
- ROBOTICS
- ARTIFICIAL INTELLIGENCE
- SOFTWARE GENERATION, VALIDATION AND MANAGEMENT
- HUMAN FACTORS

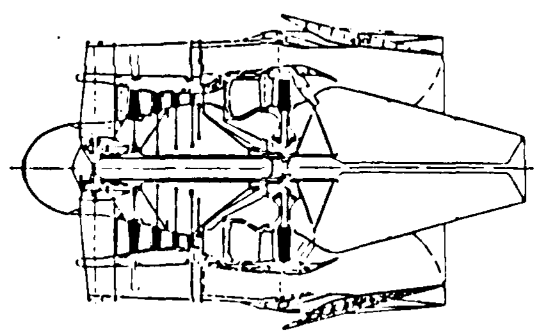
OPERATIONS

- ROBOTICS FOR GROUND ASSEMBLY AND SERVICING
- AI FOR LAUNCH PROCESSING
- INTEGRATED PROPELLANT LOGISTICS
- HAZARDOUS WARNING INSTRUMENTATION
- VERIFICATION OF MECHANICAL/ STRUCTURAL SYSTEMS
- OPERATIONS MANAGEMENT SYSTEM
- OPERATIONS SITE PRECISION WEATHER FORECASTING

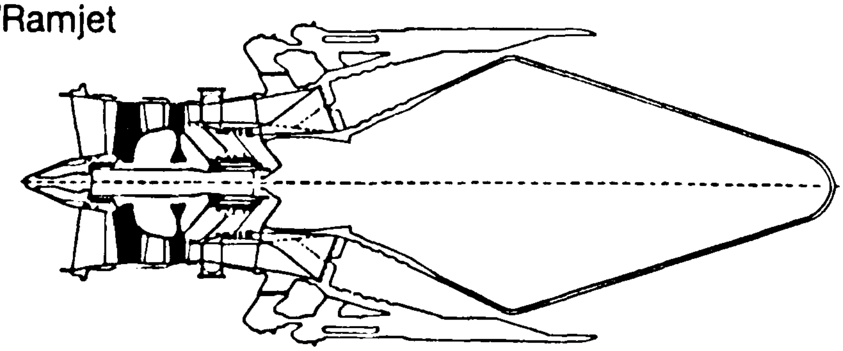
COMBINED CYCLE/SCRAMJET EFFORTS



Turboramjet



Air/Turbo/Ramjet



SCRAMJET

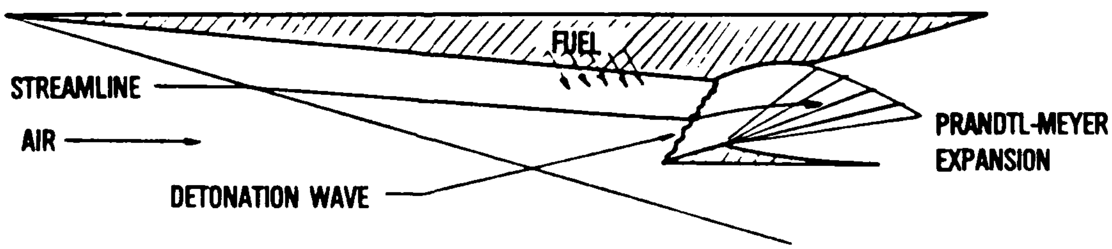
OBJECTIVE: INITIATE DEVELOPMENT OF SELECTED SCRAMJET TECHNOLOGY AREAS

APPROACH:
- MACH 6-12 FOR NOW
- COORDINATE WITH NASA/OTHER SCRAMJET EFFORTS
  - FILL TECHNOLOGY GAPS
- PROGRAM RESEARCH AND DEVELOPMENT ANNOUNCEMENT (PRDA)
  - INLET
  - COMBUSTOR
  - NOZZLE
  - STRUCTURES
  - COMPUTATIONAL FLUID DYNAMICS (CFD)
- PLAN FOR EXPERIMENTS IN FDL HYPERVELOCITY RESEARCH VEHICLE

KEY MILESTONES:

• PRDA RESPONSES	MAR 86
• FOLLOW-ON PROGRAM	FY88

WAVE ENGINE



- MACH NUMBER AHEAD OF DETONATION WAVE IS NEAR WAVE PROPAGATION SPEED. THUS, AIR FLOW DIFFUSION IS LESS.
- COMBUSTION PROCESS OCCURS BEHIND DETONATION WAVE WITHIN A FEW CENTIMETERS.
- FUEL IS ADDED WELL UPSTREAM OF DETONATION WAVE TO ESTABLISH UNIFORM FUEL-AIR MIXTURE.

LIQUID AIR CYCLE TECHNOLOGY

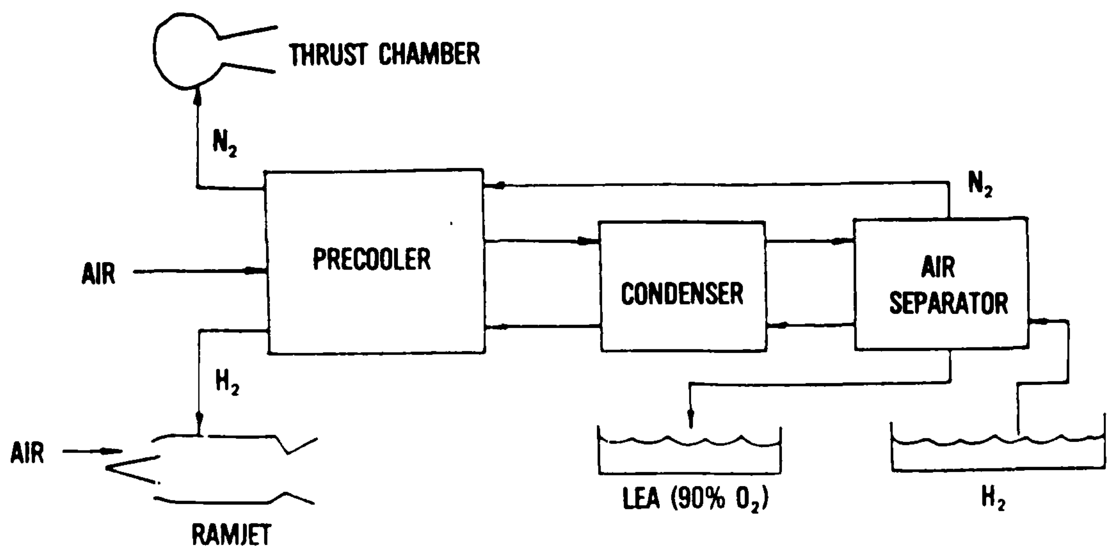
OBJECTIVE:
- OBTAIN SUBSCALE TEST DATA ON KEY ELEMENTS OF HEAT EXCHANGERS AND AIR SEPARATORS
- PROVIDE DESIGN DATABASE

APPROACH:
- APPLY MODERN FABRICATION AND MATERIALS TECHNOLOGIES
- ASSESS HEAT EXCHANGER CONTAMINATION ALLEVIATION TECHNIQUES
- UPDATE AND DEVELOP DESIGN CODES
- ASSESS VEHICLE INTEGRATION PROBLEMS AND PAYOFF

KEY MILESTONES:

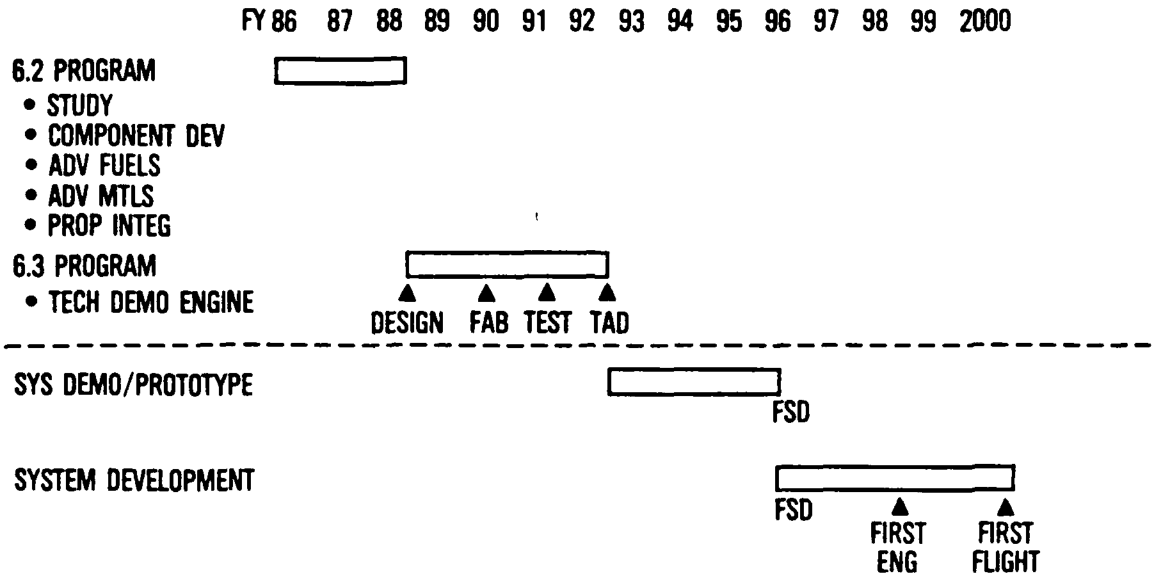
• PRDA ADVERTISED	22 SEP 86
• CONTRACT AWARD	01 MAY 87
• PROGRAM COMPLETION	3QTR FY90

LACE/ACES
DURING AIR COLLECT MODE



COMBINED CYCLE PROPULSION

PROPOSED DEVELOPMENT SCHEDULE



COMBINED CYCLE PROPULSION

SUMMARY

- AIRBREATHING ENGINES ARE MATURE DEVELOPMENTS, HIGHLY DIVERSIFIED, WIDELY DEPLOYED
- HIGH-SUPERSONIC, HYPERSONIC AIRBREATHING PROPULSION IS VERY PROMISING
- AIRBREATHING TECHNOLOGIES CAN BE SYNERGISTICALLY INTEGRATED
- ACROSS-THE-MISSION OPERATING FLEXIBILITY
- TOTAL ENGINE/VEHICLE INTEGRATION MANDATORY
- NEW CONCEPTS ON THE HORIZON
- MEET FUTURE AIR FORCE AEROSPACE MISSIONS

AEROSPACE POWER TECHNOLOGY

Supports development an thermal management of solar power, fuel cells, batteries, hydraulics, and power conversion, conditioning and transmission devices for both space and flight vehicle applications. These analytical and experimental efforts form a balanced, broad power subsystem technology base. Current goals include increased power output, decreased weight and volume, decreased vulnerability, increased life and reliability, and increased environmental tolerance for future systems.

PREMISES

1. Fast Means Hot
   Electrical: From 125 Degrees C to 200 Degrees C
   Hydraulic: From 180 Degrees C to 300 Degrees C
2. Combined cycle Propulsion means new thinking on auxiliary power system design philosophy

PROGRESS

1. POWER SEMICONDUCTORS
   Sandia National Laboratory
   300 Degrees C
   0.50 Amperes, 100 Volts

2. CAPACITORS
   Output Filter for VSCF
   200 Degrees C
   Kapton Dielectric

3. POWER SYSTEMS
   400 H_z, 40/60 KVA
   Rotating Diodes
   Magnetics
   Cooling Fluid

FY87 NEW START PROGRAM

Power System Architectures for High Mach Vehicles

OBJECTIVE: Provide Vehicle Power Technology Options for Manned High Mach Vehicles
- Endoatmospheric
- Endo/Exoatmospheric

APPROACH: Establish Performance and Configuration Requirements
Develop Power Options and Provide Basis for System Selection and Hardware Development
- Environmental Control Systems
- Actuation
- Starting
- Electrical

MILITARY PAYOFF: Provides Enabling Technology in the Auxiliary Power Area

TECHNICAL CHALLENGES

FUELS

- IMPROVE THERMAL STABILITY (PREVENT COKING)
- OPTIMIZE COOLING CAPACITY

CATALYSTS

- DEVELOP APPLICATION METHOD
- PROVIDE IN-SITU ACTIVATION
- MAINTAIN ACTIVITY

COMBUSTION

- RAPID, LOW-PRESSURE-LOSS MIXING
- REDUCED IGNITION DELAY
- FAST KINETIC RATES

FUEL SYSTEM

- MANAGE HEAT TRANSFER
  - DESIGN
  - MATERIALS
  - COMPONENTS
  - TRANSFER MEDIA
- ACHIEVE HIGH MASS FLOW
- HANDLE CHANGING FUEL CHARACTERISTICS
- MINIMIZE SIZE/WEIGHT/COST
- MAXIMIZE DURABILITY

CANDIDATE HYPERSONIC FUELS

	HYDROGEN	METHANE	METHYL CYCLOHEXANE
LIQUID DENSITY, LB/GAL	0.59	3.54	6.44
BOILING POINT, °F	-423	-258	+ 213
HEAT SINK, BTU/LB (FROM B.P. OR 60°F TO 1340°F)	6300	1158	1905 *
HEAT OF COMB., BTU/LB	51,600	21,500	19,530 *
HEAT OF COMB., BTU/GAL	30,444	76,110	125,773 *
RATIO: HEAT SINK/HEAT COMB.	0.122	0.054	0.098

* INCLUDES ENDOTHERMIC REACTION OF METHYL CYCLOHEXANE TO HYDROGEN AND TOLUENE AT 100% CONVERSION.

SPACECRAFT

AEROSPACE POWER TECHNOLOGY

This project supports development and thermal management of solar power, fuel cells, batteries, hydraulics, and power conversion, conditioning and transmission devices for both space and flight vehicle applications. These analytical and experimental efforts form a balanced, broad power subsystem technology base. Curent goals include increased environmental tolerance for future systems.

FY 1986 Program - A three terminal, 22 percent efficient multi-bandgap solar cell will be demonstrated.

FY 1987 Planned Program - A program to demonstrate a 30% multibandgap solar cell will be demonstrated. A program to investigate the critical technology areas associated with thermionic energy conversion will be initiated. *The development of the technology leading to a heat pipe radiator for sodium sulfur space batteries will be initiated. A high temperature hydraulic seal program will be initiated. The foil bearing program for space turbo-machinery will be continued.

FY 1988 Planning Program - The fault tolerant electrical system program will be completed. The VHSIC insertion into the electrical system program will be continued. The multi-bandgap solar cell program will be continued. Thermionic technology and the sodium-sulfur heat pip radiator programs will be continued. The high temperature hydraulic seal program will be continued. A program investigating actuation technologies for National Aerospace Plane (NASP) and hypersonic vehicles will be initiated. The space turbo-machinery foil bearing program will be completed. The high power density missile battery development will continue. This project develops the non-nuclear power technology base for Air Force systems and is coordinated with the Strategic Defense Initiative (SDI) office to insure there is no duplication of space power efforts.

PROJECT FORECAST II
PT - 05, SPACE POWER

DESCRIPTION

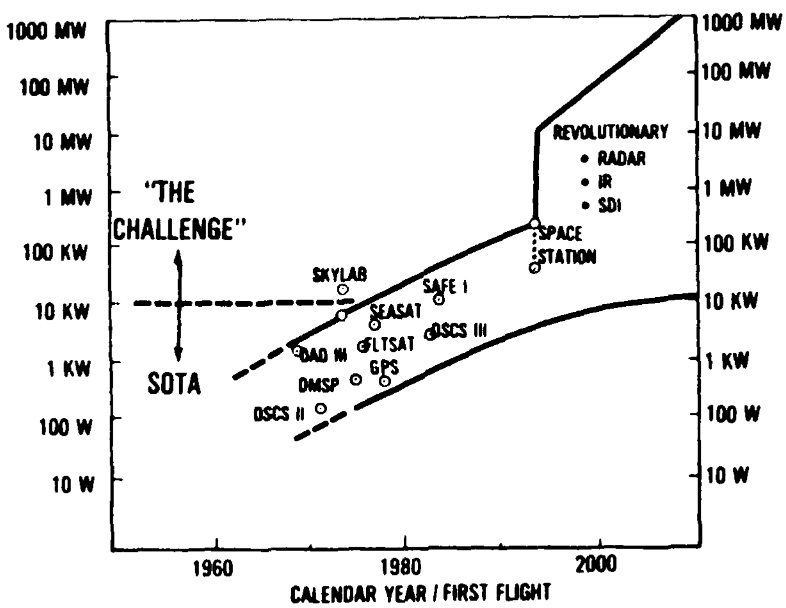
A 6.1, 6.2 AND 6.3 PROGRAM TO DEVELOP AND DEMONSTRATE SURVIVABLE, HIGHER POWER LEVEL CAPABILITIES FOR FUTURE AIR FORCE SPACE MISSIONS. TECHNOLOGIES TO BE DEVELOPED INCLUDE

- O PHOTOVOLTAICS
- O ELECTROCHEMICAL ENERGY STORAGE
- O THERMAL CONTROL
- O POWER PROCESSING / DISTRIBUTION
- O ADVANCED ENERGY CONVERSION CONCEPTS

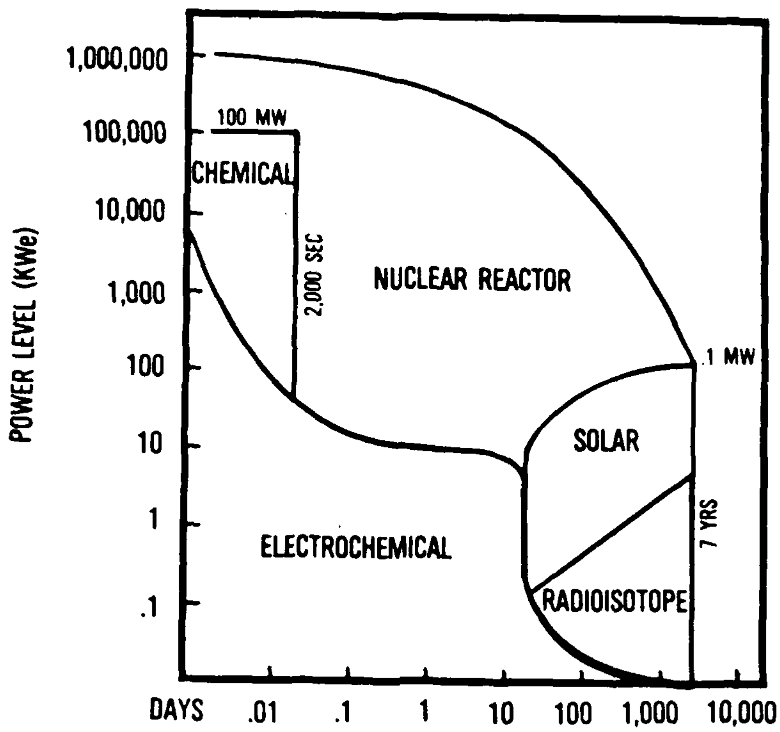
PAYOFFS

- O MISSION ENABLING SPACECRAFT POWER FOR NUMEROUS PLANNED SPACE MISSIONS AT POWER LEVELS GREATER THAN 10 KILOWATTS
- O SURVIVABILITY TO LASER AND NUCLEAR THREATS
- O AFFORDABILITY THROUGH SIGNIFICANT DECREASES IN WEIGHT AND VOLUME WHICH REDUCE LAUNCH COSTS AND ELIMINATE POWER SYSTEM ON - ORBIT ASSEMBLY

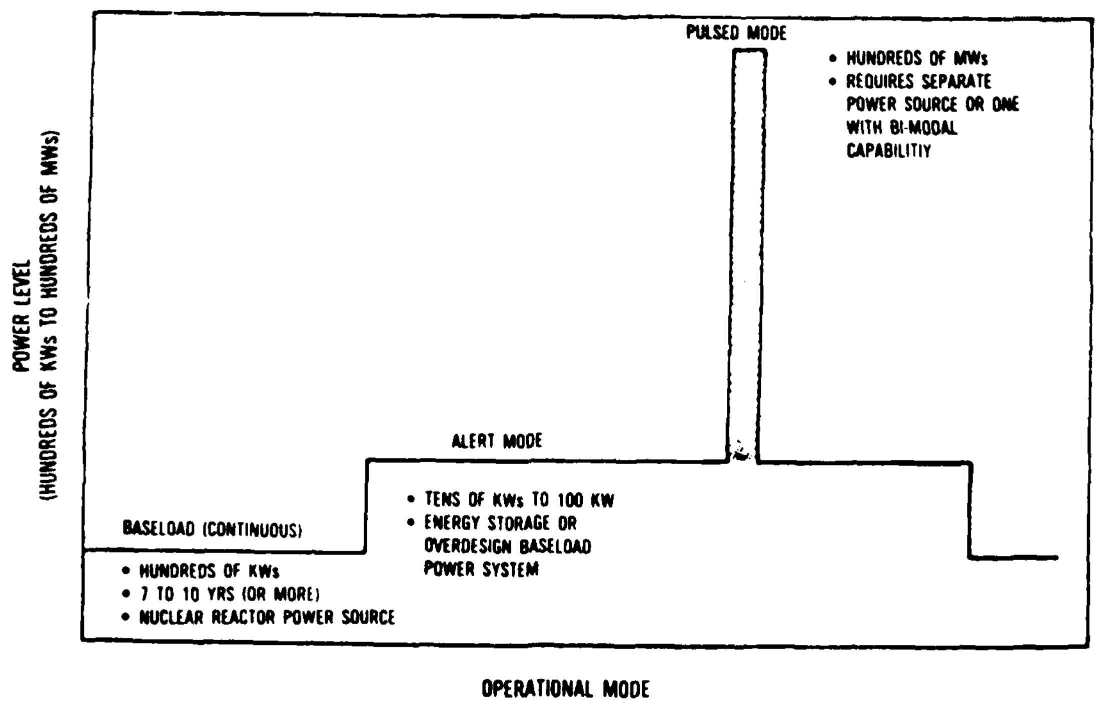
ELECTRICAL POWER TRENDS
SPACECRAFT



POWER SOURCE OPTIONS VERSUS POWER LEVEL AND OPERATING TIME



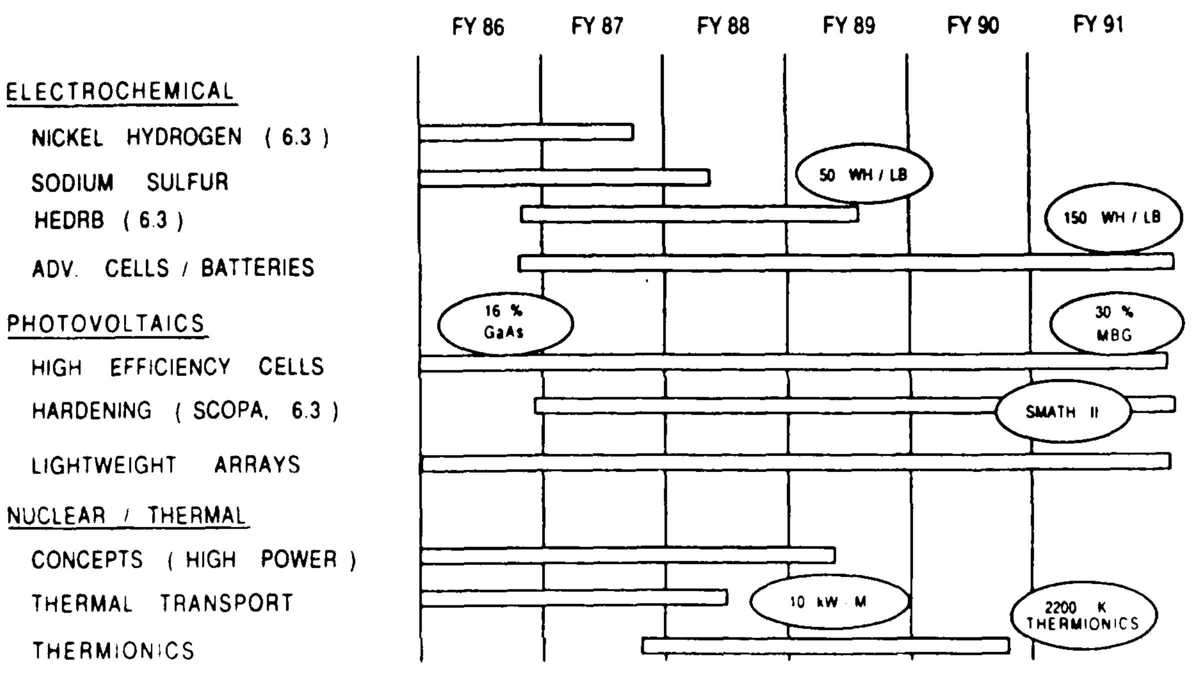
HYPOTHETICAL MISSION LOAD PROFILE



SPACECRAFT POWER
GOALS

- O LIGHTWEIGHT POWER PROCESSING TECHNOLOGY
- O 2200 DEGREE K THERMIONIC TECHNOLOGY
- O 10 kW - M THERMAL TRANSPORT SYSTEM
- O 50 WH / LB, 100 W / LB, GEOSYNCHRONOUS ORBIT BATTERIES (FLIGHT QUALIFIED)
- O 35 WH / LB, 150 W / LB, LOW EARTH ORBIT CELLS
- O HIGH EFFICIENCY PHOTOVOLTAICS (11 - 18 % TO 30 %)
- O HARDENED ARRAY (SMATH II)
- O LIGHTWEIGHT SOLAR BASED POWER SYSTEMS

SPACECRAFT POWER ROADMAP



TECHNOLOGY DICIPLINES

SOURCE ENERGY
- ELECTROCHEMICAL
- CHEMICAL
- SOLAR
- NUCLEAR REACTOR
- RADIOISOTOPE

POWER CONVERSION
- FUEL CELL
- TURBOALTERNATOR/GENERATOR
- PHOTOVOLTAIC
- THERMOELECTRIC
- THERMIONIC
- DYNAMIC CYCLES (BRAYTON RANKINE, STIRLING)
- MHD
- AMTEC

SHAFT POWER
- GAS DRIVEN TURBINE

THERMAL
- STORAGE (SOURCE,SINK)
- TRANSPORT
- REJECTION

ENERGY STORAGE
- BATTERIES
- HYDROGEN/OXYGEN
- FLYWHEELS
- COMPRESSED FLUIDS
- CRYOGENIC INDUCTORS
- CAPACITOR BANKS

CRYOGENIC TECHNOLOGY
- STORED CRYOGENS
  - HYDROGEN
  - OXYGEN
  - HELIUM
  - NITROGEN
- CRYOGENIC TANKS
- CRYOGENIC REFRIGERATION
- REACTANT FEED SYSTEMS
- CRYOGENIC PUMPING

ENVIRONMENTAL INTERACTIONS
- EFFLUENT
- PLASMA COUPLING
- ATTITUDE DISTURBANCE
- RADIATION
- TORQUE/VIBRATION

POWER CONDITIONING
- HIGH VOLTAGE
- HIGH CURRENT
- HIGH POWER

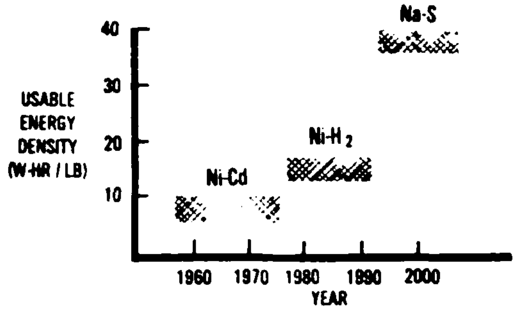
POWER CONDITIONING, DISTRIBUTION & CONTROL
- HIGH VOLTAGE SWITCHING
- HIGH CURRENT SWITCHING
- BUS CONDUCTORS
- HV CONNECTIONS / FEEDTHROUGHS / TERMINATIONS
- DIELECTRIC INSULATION

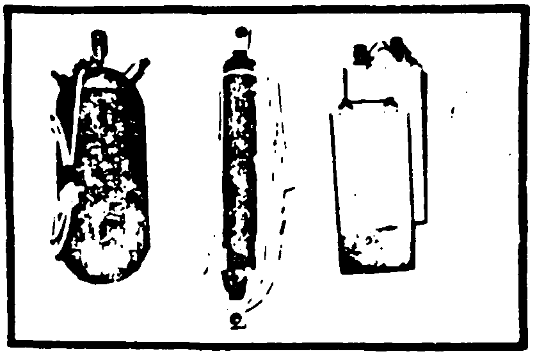
ELECTROCHEMICAL POWER SOURCES : SPACECRAFT BATTERIES

THE TECHNOLOGIES

- NICKEL-HYDROGEN
- SODIUM-SULFUR

STATUS

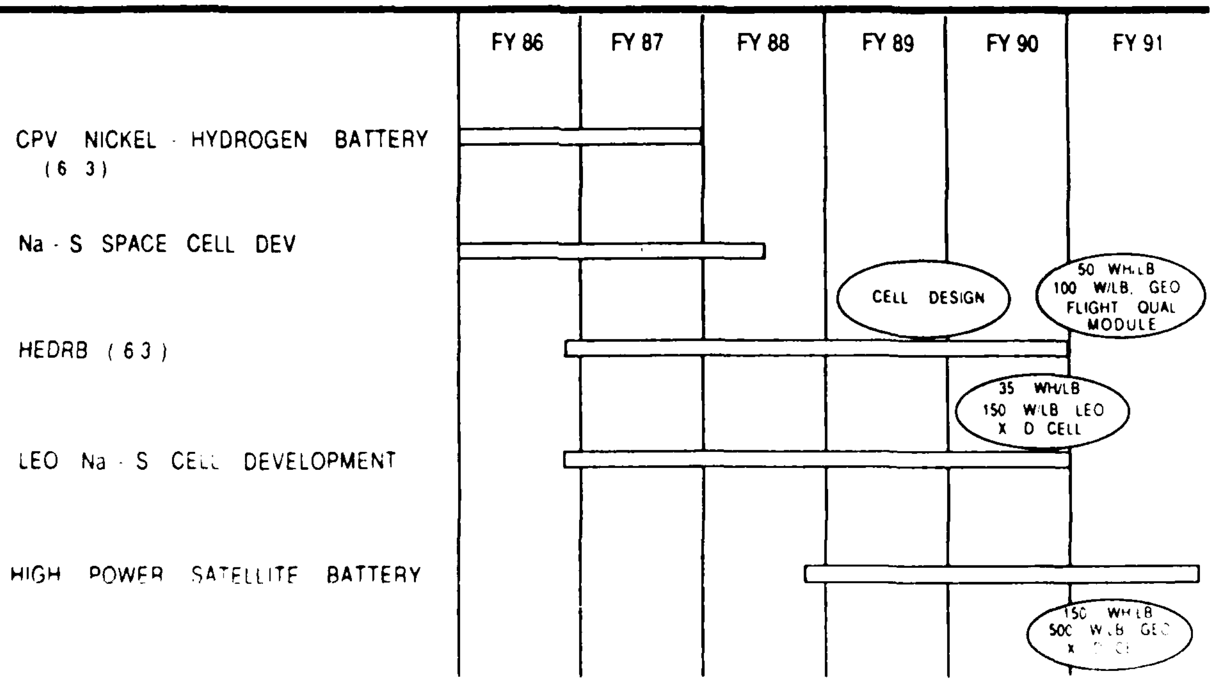




THE GOALS

- NICKEL-HYDROGEN
  - HIGHER CAPACITY
  - 30,000 CYCLES (5 YEARS - LEO)
- SODIUM-SULFUR
  - 40 WATT-HOURS / POUND
  - 15,000 CYCLES

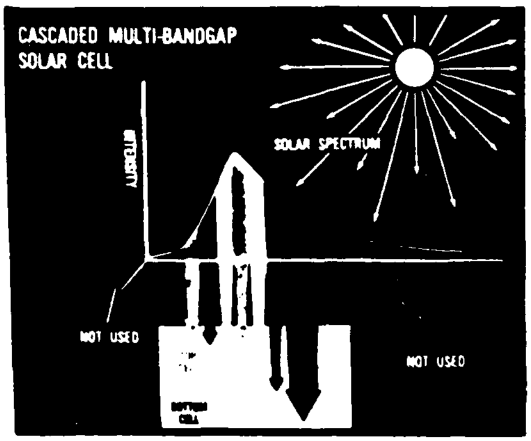
SPACECRAFT POWER ROADMAP ELECTROCHEMICAL



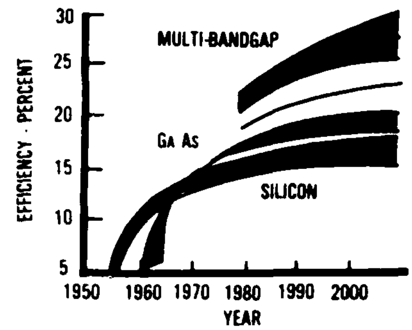
PHOTOVOLTAICS: CELL DEVELOPMENT

THE TECHNOLOGIES

- SILICON CELLS
- GALLIUM ARSENIDE (GaAs) CELLS
- MULTI-BANDGAP (MBG) CELLS



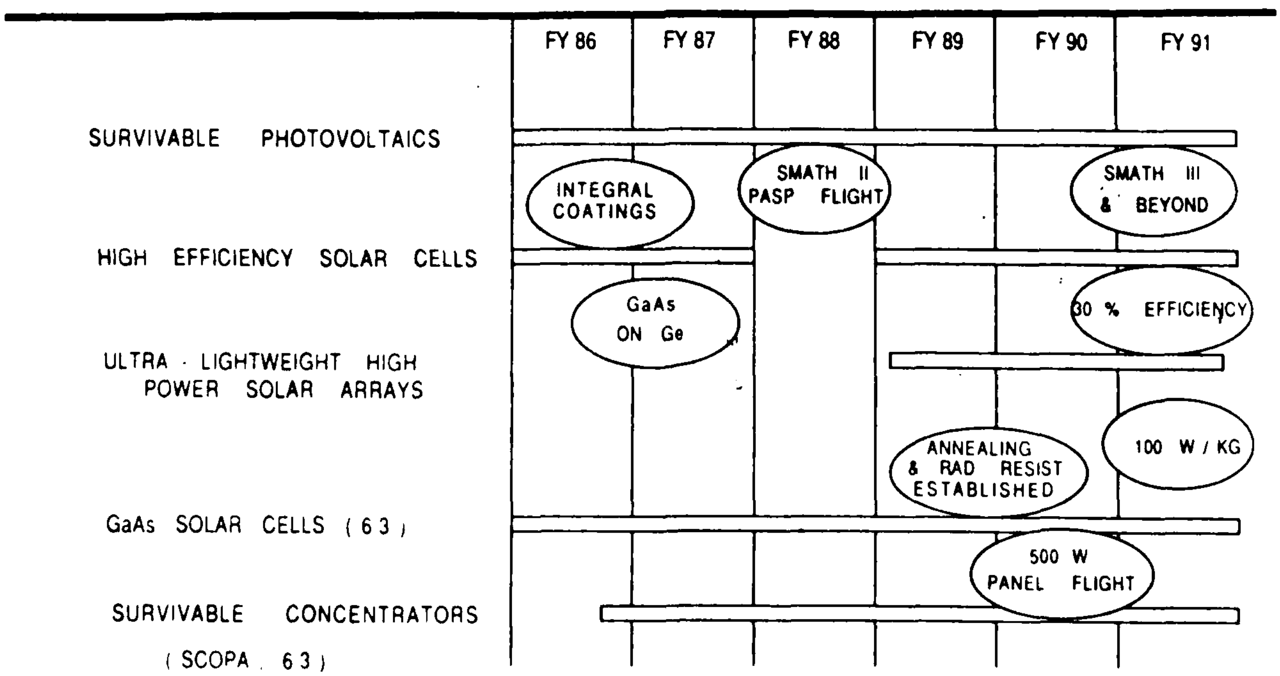
STATUS



THE GOALS

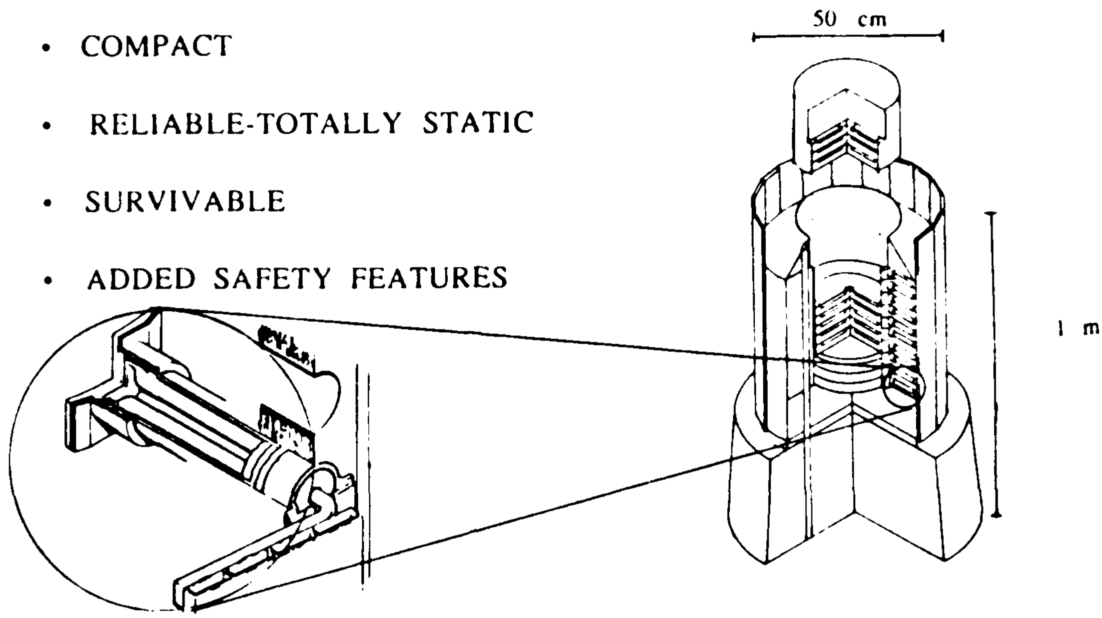
- 25 - 30% EFFICIENCY
- THIN AND RUGGED
- RADIATION HARD
- SURVIVABLE

SPACECRAFT POWER ROADMAP
PHOTOVOLTAICS



THERMIONIC SPACE POWER 5-25 kW(e)

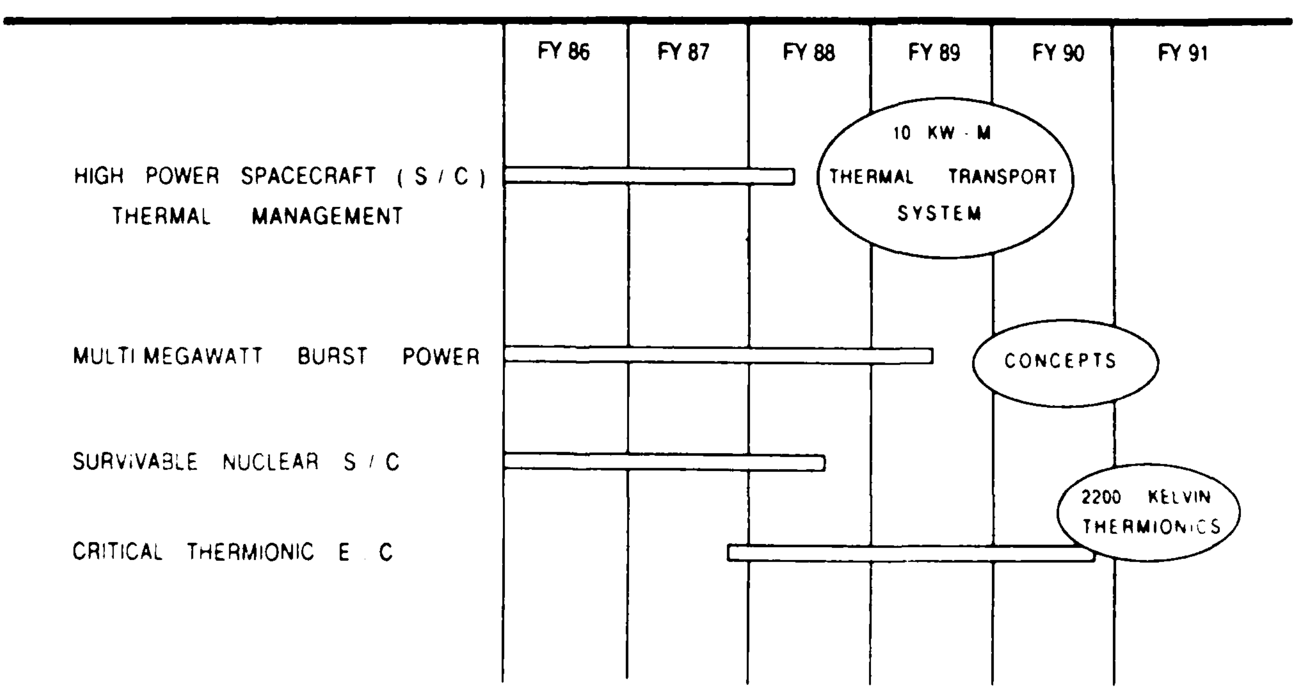
- COMPACT
- RELIABLE-TOTALLY STATIC
- SURVIVABLE
- ADDED SAFETY FEATURES



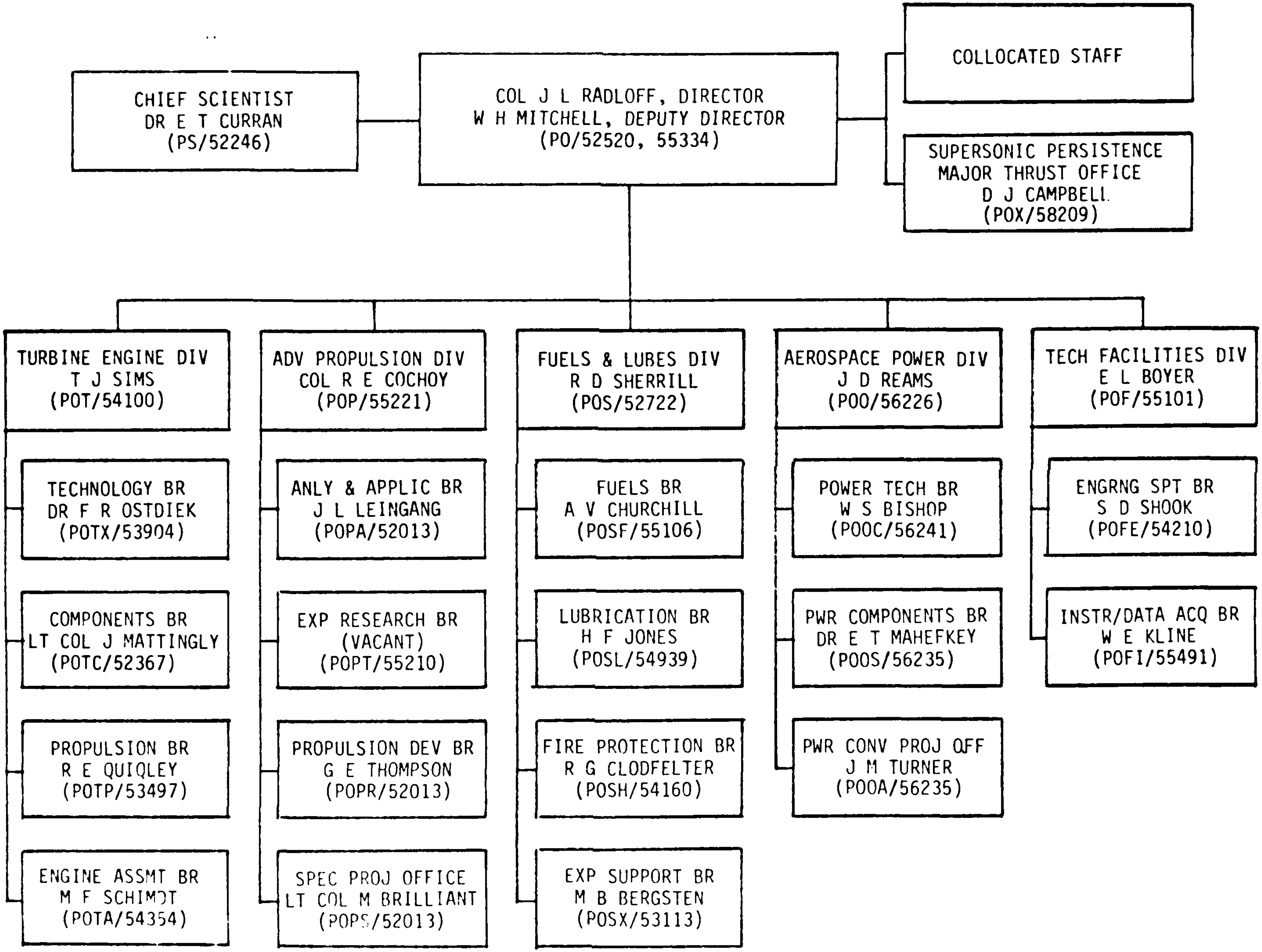
CONVERTER-RADIATOR

REACTOR HEAT SOURCE

SPACECRAFT POWER ROADMAP
THERMAL



APPENDICES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J L LEINGANG
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(VACANT)
(POPT/55210)
PROPULSION DEV BR
G E THOMPSON
(POPR/52013)
SPEC PROJ OFFICE
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(POPS/52013)
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R D SHERRILL
(POS/52722)
FUELS BR
A V CHURCHILL
(POSF/55106)
LUBRICATION BR
H F JONES
(POSL/54939)
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POWER TECH BR
W S BISHOP
(POOC/56241)
PWR COMPONENTS BR
DR E T MAHEFKEY
(POOS/56235)
PWR CONV PROJ OFF
J M TURNER
(POOA/56235)
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FACILITIES

SUMMARY: The Aero Propulsion Laboratory's Technical Facilities are located on Wright-Patterson AFB. Included in the Facilities complex are the following:

A. Air-Breathing Propulsion Facilities

1. Turbine Engine Facilities

These facilities provide the analytical and physical research and test laboratories required to develop turbine engine and component technology to satisfy future requirements. Sub-Laboratory areas with the facility are: (1) A satellite computer used for turbine engine control system development, as well as to support general engineering computation and analysis requirements for the Aero Propulsion Laboratory; (2) A turbine-component heat-transfer facility to investigate approaches and refine methods of cooling turbine blades for the high turbine-inlet-temperature regime and to investigate candidate instrumentation approaches for measuring turbine-inlet gas and turbine blade metal temperatures; (3) Four sea level turbine engine tests stands with up to 15,000 lb thrust capability. One air-breathing engine altitude chamber with simulation to 50,000 ft at Mach 1.5 and a maximum of 3,000 lbs force thrust; (4) Sea Level Test Stand with 60,000 lb thrust capability and 2,000 pps airflow. This is a fully computerized research test facility and represents one of the most modern in the Air Force. It is currently being utilized for full scale lubricant and alternate fuel development engine testing; (5) A single stage 2,000 HP compressor test facility including open and closed loop operation; and (6) A holography laboratory which is used for the development and application of laser holographic measurement techniques including image derotation and triple-pulsed laser holography as applied to the structural dynamic response of turbine engine components.

Compressor Research Facility: The Compressor Research Facility supports the Laboratory's exploratory and advanced development efforts in compressor technology by providing reliable experimental test data in a timely manner. This facility lets the Air Force independently evaluate full-scale, multi-stage, single spool, fans and compressors under operating conditions similar to an actual flight profile.

The facility can handle most compressors from operational engines and will be used to obtain updated compressor performance maps. The facility will provide the means of improving state-of-the-art gas turbine compressors. In addition, the facility is automated and computer controlled to study steady-state and transient phenomena on full size test articles. The performance characteristics are:

a. Speed/Range - 3,000 - 16,000 RPM at 30,000 HP
16,000 - 30,000 RPM at 15,000 HP
b. Air Flow Rate - 15-500 lbs/sec
c. Inlet Press Range - 2 psia (ambient)
d. Discharge Press Range - Up to 588 psia
e. Discharge Temp Range - Up to 1490°F
f. Data Acquisition Rate - 50,000 samples per sec

The facility is supported by two sub-laboratory areas which are: (1) A flow calibration facility used for testing a full range of static and high-response aerodynamic probes along with various compressor inlet configurations and flowmeters; and (2) a laboratory which provides holographically determined resonant frequencies and mode shapes of compressor blades, vanes and instrumentation probes to ensure safe operation of test articles installed in the Compressor Research Facility.

2. Ramjet Engine Facilities

Flow Visualization Facility: A water tunnel is used to economically investigate flow patterns in complicated geometrics of proposed and current ramjet engines. The data generated will reduce more costly "hot flow" testing required to develop or improve ramjet engines.

The Ramjet Combustion Research Facility: Is equipped as a general purpose test area for various research needs associated with ramjet component research and development. It consists of a small scale direct connect thrust stand capable of air flow rates of up to 15 lbs/sec and a small scale M-3 freejet wind tunnel. The facility is also equipped with a Laser Doppler Velocimeter System for optical velocity measurements of the internal gas flow.

B. Aerospace Power Facilities

1. Plasma Physics and Optical Diagnostics Research Laboratory: This facility is equipped to conduct research and obtain reliable data for plasma generation, electric discharge lasers, optical sources, and counter-measures. Laboratory test stands, experimental closed cycle lasers, spectrometers. and computerized data acquisition systems are typical of the equipment available.

2. High Power Laboratory: This facility supports high power component and system development programs. The facility can provide up to five megawatts for testing of capacitive, inductive, and plasma energy storage and switching networks. Superconducting transient effects may also be investigated.

3. Aircraft Power Laboratory: This facility includes a capability to test hydraulic system components, electrical generation systems, and high speed mechanical components such as torque converters. A high speed drive stand is capable of over 300 HP and 100,000 RPM. Three 350 HP drive stands are available for driving electrical generators (parallel or series) and are computer controlled. Acquisition, storage, and manipulation of test data are done by computer to a sensitivity level of a fraction of one cycle of a 400 Hz output.

4. Solar Cell Evaluation Laboratory: This facility is used to test experimental solar cells and array segments. The test equipment includes: A 3 foot by 3 foot vacuum chamber for thermal cycling and UV radiation life testing; a spectrosun X25 solar simulator and filter wheel; ultrasonic cleaning and welding equipment for contact assembly; and optical equipment for flatness determinations.

5. Battery Laboratory: This facility consists of environmental test chambers, automatic life cycling equipment, instruments for electro-chemical analysis and complete gas chromatography, Surface-Area/Pore-Volume Analyzer, flame spectrophotometer, scanning electron microscope, and a chemical laboratory. Test equipment includes a cycling rack, computer controlled aircraft battery evaluation stand and many auxiliary racks. Fabrication of battery cells such as lithium organic electrotype cells is accomplished in special experimental investigations.

C. Fuel, Lubrication and Fire Protection Facilities

1. Lubricant Research Facilities: The performance of lubricants is determined under laboratory conditions, test stand turbine engine conditions, and operational conditions. Lubricant stability is determined using the Squires technique, oxidative-corrosion testing, and cokers. Condition is assessed using gas, high pressure liquid, and thin film chromatographic techniques, infrared spectroscopy, and standard lubricant tests. Wear metals are studied using emission spectrometry, ferrography, and scanning electron microscopy.

2. Lubrication Systems Research Facilities: Bearing dynamics are investigated in full scale tests operating at realistic conditions of load, speed and temperature. In addition, rolling contact fatigue tests are performed to determine the effect of advanced bearing materials, coatings, and processes on bearing fatigue life. The facilities also permit study of lubricant physical properties, including viscosity at high pressure, tractive force, and film forming capability.

3. Fire Protection Research Facilities: A variety of specialized equipment including test chambers and instrumentation is available to provide for the investigation and evaluation of combustibility, extinguishant capability, flame propagation and auto ignition characteristics of flight vehicle materials, fuels and lubricants. Fire, explosion, and overheat detection devices are studied and evaluated. Electrostatic hazards are simulated and ignition sources are identified through the use of test equipment which includes a flame tube and a fuel tank electrostatic simulator.

4. Combustion Research Facilities: Consists of a combustion test cell with a remote control room. Two test articles can be installed at the same time in parallel lines. Air is supplied at flow rates and pressures up to 3.4 kg/s and 275 psig, respectively. Liquid fuel can be supplied at flow rates and pressures of 4 gpm and 600 psig, respectively. A wide variety of gaseous fuels can also be supplied. A dedicated computer system, including tape and disk storage, printer and plotter are available for data acquisition and analysis. An emission sampling and analysis system uses extraction probes to measure various exhaust gases and permit calculation of combustion efficiency. The capability exists for measuring velocities and temperatures using conventional probes. In addition, an optical diagnostic device is available that can make simultaneous temperature, nitrogen, and oxygen measurements in 10 nanoseconds at a repetition rate of 15 per second and a second device can measure two velocity components simultaneously at rates up to 100,000 realizations per second.

5. <u>Fuels Research Facilities</u>: Fuel storage characteristics at 40°F-130°F, fuel heat transfer and heat sink characteristics are investigated using a variety of thermal stability, reactor, and heat exchanger devices. Liquid and slurry lubricity and rheology are determined using appropriate equipment. Analytical laboratory capabilities include high resolution gas chromatography, liquid chromography, infrared spectroscopy, nitrogen determination by chemiluminescence, and hydrogen content by wide-line nuclear magnetic resonance. Fuel storage and blending equipment permits preparation of fuel blends in lots up to 25,000 gallons.

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